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Modeling the dairy industry
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In This Issue

"A carpenter and a geometer investigate the right angle in different ways." Take a sentence like that out of its original context and you can read many ideas into it. The sentence is from Aristotle. I have seen it quoted in various places. Each time, a different interpretation was put on it. So I looked it up in the Nicomachean Ethics (Book 1, 1098a) and found that the segment quoted above ends with a semicolon. The rest of the sentence is "the former does so in so far as the right angle is useful for his work, while the latter inquires what it is or what sort of thing it is; for he is a spectator of the truth."

The sentence comes just after Aristotle has outlined a great truth and informed us that anyone is capable of filling in the details later. The work of the carpenter is subordinated by Aristotle to minor questions of detail; the geometer contemplates truth.

The frequently quoted first segment implies no necessary ranking of the relative values of carpenters and geometers in society, but the second part of the sentence—in context—does. I understand that Aristotle really meant it as a put-down of carpenters. Geometers, on the other hand, he ranks among the elite.

If my interpretation is correct, then I do not like Aristotle's innuendo about superior and inferior occupations. The functions of both the geometer and the carpenter are equally noble and—to make a pun of it—worthy of the Nobel Prize. Let me illustrate with two prize winning scientists, one a carpenter and the other a geometer.

Linus Pauling, winner of the Nobel Prize for Chemistry, tells an anecdote about his first meeting with Albert Einstein. Pauling had just given a seminar on quantum mechanics and the chemical bond. Einstein was in the audience. Afterwards, when he was asked what he thought about the seminar, Einstein said it was "too complicated" for him. Pauling concludes: "He was interested in what was going on in the understanding of the structure of molecules, but in a rather general way rather than in the detailed way in which I am interested." Pauling sees himself as one of Aristotles' carpenters and Einstein as a geometer. But unlike Aristotle, Pauling sees no reason to feel inferior about it.

The articles in this issue illustrate that there is some of the geometer and some of the carpenter in all good agricultural economists. We contemplate and outline eternal truths; we also fill in needed details.

This journal carried an overview of USDA's Food and Agricultural Policy Simulator (FAPSIM) in its April issue. The model is used by USDA economists to forecast prices and quantities for 13 agricultural subsectors and it estimates cash receipts, expenses, and net farm income. In this issue, the authors present details of the dairy subsector of FAPSIM. The dairy sector contains 46 equations and can be run as a stand-alone model. However, 11 of its exogenous variables are endogenous to FAPSIM so the model can also be run allowing for relevant feedback loops with the other livestock and crops sectors. The authors compare runs done both ways. The comparison raises—and offers empirical answers to—some interesting questions about the validity of fitting and running models that are known in theory to be subsectors of larger systems.

If FAPSIM with its 360 equations seems like too large a model for your tastes, the second article in this issue describes a three-equation system. The three variables are food at home, food away from home, and nonfood consumer purchases. These three variables are related to one another according to the microeconomic theory of consumer demand. Appropriate assumptions reduce the three equations to two. But they turn out to be a formidable looking, interlocked pair. A canned software package for nonlinear regression is called upon to fit the system. The result is a useful set of empirical estimates of factors affecting the demand for food couched in a small system of equations that satisfy the requirements of economic theory.

The third article is also concerned with demand for farm products. It was found that single-equation methods for fitting equations failed to provide usable results because variables which statistical theory assumes to be independent were in fact highly correlated. The author turned to a method for doing regression on the principle components of the data instead of on the original data. The method has been in the literature for a decade or more, but it is not used extensively. Some might object that "if you start with multicollinearity, no statistical manipulation can possibly sort out reliable partial regression coefficients!" On the other hand, it is difficult to argue with success. Using principle components regression, the author found that variables which had the wrong sign according to economic theory using ordinary least squares regression righted themselves and that variables which were not statistically significant became so. The cost of this success, the author openly admits, is biased coefficients.

The final article in this issue raises an important question. The author asks whether the measure of net farm income

which is regularly published by ERS is as useful as it might be. One of his concerns is that it is income after taxes that affects farm management decisions and farmer well-being. The costs of buying a tax shelter may be reflected in the estimate of farm expenses, but the benefits are not reflected in the estimates of income. His other concern is that capital gains from inflation are not allowed for. Capital gains on the land owned by farmers can exceed net income. And, farmers can use these capital gains as collateral to borrow money for expansion of the farm business. Recent experience with inflation and the tax laws call into question whether the income statement and the balance sheet really tell us what we need to know.

Clark Edwards

Contents

The Food and Agricultural Policy Simulator: The Dairy-Sector Submodel

Larry E. Salathe, J. Michael Price, and Kenneth E. Gadson*

Abstract

This article presents the structure, parameters, and validation statistics for the dairy-sector submodel contained in the U.S. Department of Agriculture's (USDA's) Food and Agricultural Policy Simulator (FAPSIM). This submodel endogenously estimates dairy cow numbers; milk production; farm-level milk prices; fluid milk consumption; and the supply, utilization, and prices of butter, cheese, nonfat dry milk, condensed and evaporated milk, and frozen milk products. It also endogenously estimates USDA purchases of manufactured dairy products and the costs of Government dairy product purchases under alternative dairy price-support options. The annual model is used to examine the adjustment resulting from lowering dairy price-supports from 75 to 65 percent of parity.

Keywords

Dairy products, econometric model, milk, policy analysis, simulation

Introduction

U.S. dairy policy has been under continuous debate since 1972. During the midseventies, debate focused on dairy import quotas (*1*).[1] Recently, large Federal budget outlays resulting from dairy price-support operations have raised questions concerning the Government's role in the U.S. dairy industry. Because of Government involvement in the dairy sector through dairy price supports, dairy import quotas, and milk marketing orders and agreements, it is likely that dairy policies and programs will remain under considerable scrutiny.

Researchers have developed a variety of economic models to examine and evaluate alternative dairy policies and programs (*2*, *3*, *6*, *8*, *9*). Such models have generally recognized interrelationships among the dairy, feed-grain, and beef and veal sectors, but they have treated such sectors as exogenous. The failure to endogenize the beef and veal and the feed-grain sectors could result in substantial errors when researchers analyze dairy policies.

The U.S. Department of Agriculture's (USDA) Food and Agricultural Policy Simulator (FAPSIM) is an annual econometric model of the agricultural sector (*10*). FAPSIM consists of a set of individual commodity models for beef, pork, dairy, chickens, eggs, turkeys, corn, grain sorghum, barley, oats, wheat, soybeans, and cotton that are linked via common variables. The model estimates a price-quantity equilibrium solution that is simultaneously consistent across all commodity sectors. This report details the dairy sector of FAPSIM. We present the dairy submodel's structure, equation parameter estimates, validation statistics, and linkages to other FAPSIM submodels. We use the dairy submodel to explore the effects of lowering the price-support level on dairy products from 75 to 65 percent of parity.

Structure of the Dairy-Sector Submodel

The dairy-sector submodel explicitly recognizes the role of the Federal Government in milk marketing and pricing.[2] The Government supports the price of manufacturing milk (and of milk eligible for fluid consumption) by purchasing manufactured dairy products. The support level for manufacturing milk is set at some fraction of parity as determined by the Congress. This support level is then adjusted by a processing allowance to derive the price at which the Government will then purchase butter, cheese, and nonfat dry milk. These purchases increase the demand for manufactured dairy products and the price of milk. When prices of manufactured products reach 110 percent of designated purchase levels, the Government may release accumulations of manufactured

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[1] Italicized numbers in parentheses refer to items in the References listed at the end of this article.

[2] The model presented draws upon earlier work by Novakovic and Thompson (*6*) and Salathe (*9*). Major structural differences between the model presented and previous studies are in the supply relationships for manufactured dairy products and Government stock specifications.

dairy products. Such releases increase supplies and lower milk prices. Because the Government supports milk prices by purchasing butter, cheese, and nonfat dry milk, Government purchases of such products depend on the level of supply and demand for each product.

The dairy submodel consists of four subcomponents: (1) milk supply, (2) milk price, (3) milk manufacturing, and (4) commercial demand.

Milk Supply

The milk supply component contains equations for dairy cow slaughter, additions to the dairy cow herd, dairy cow numbers, milk production, milk fed to calves, milk sold to plants and dealers, and the supply of milk eligible for fluid consumption. An identity (equation) is used to determine the ending inventory of dairy cows on farms based on the beginning inventory of dairy cows, death loss, dairy cow slaughter, and additions to the dairy cow herd. This identity is the following:

$$\text{COWSNMC}(+1) = 0.98\ \text{COWSNMC} + \text{COWSEMC} - \text{COWKSMC}$$

where:

COWSNMC = the number of dairy cows on farms on January 1,

COWSEMC = the number of additions to the dairy cow herd during the year, and

COWKSMC = the number of dairy cows slaughtered during the year.

This identity assumes that 2 percent of all dairy cows die during each calendar year. Data on the actual number of dairy cow additions are not available. Therefore, we assume that 60 percent of all dairy cow replacements over 500 pounds on January 1 are added to the dairy herd during the calendar year. Although both assumptions are open to debate, they were necessary if the dairy and beef and veal sector submodels were to be linked. For example, data on dairy cow slaughter can be generated by use of the identity. Such a data series is otherwise unavailable. Yet, without such a data series, it would be impossible to estimate either the contribution of dairy cow slaughter to total beef production or the effects of beef and milk prices on dairy cow slaughter.

Dairy cow slaughter and additions to the dairy cow herd are hypothesized to be influenced by the price of milk, the price of cattle, the price of feed, and the stock of dairy cows. The ratio of the price of milk relative to the price of cattle and the ratio of the price of milk to the price of feed reflect the relative profitability of keeping rather than selling dairy heifer calves and dairy cows. The price of feed is calculated as a weighted (reflecting average importance in dairy rations) average of the prices of corn, oats, grain sorghum, barley, wheat, and soybean meal. This variable links the dairy sector to the crops submodels.

Milk production per cow is a function of lagged milk production per cow, a time trend, and the ratio of milk price to the price of feed. The time trend captures improvements in management practices over time such as improved culling and breeding practices. We included the ratio of milk price to the price of feed on the assumption that farmers reduce feeding rates during periods when milk prices are low relative to feed costs.

The fraction of milk eligible for fluid consumption has steadily increased over time. Salathe (*9*) found that at least a portion of the increase could be explained by the lagged difference between the producer prices for fluid and manufacturing grades of milk. Therefore, the supply of milk eligible for fluid consumption is hypothesized to be related to the lagged difference in producer prices for fluid and manufacturing grades of milk and to the quantity of milk sold to plants and dealers.

Milk Price

The milk price component is consistent with the pricing mechanism for Federal milk marketing orders. The Minnesota-Wisconsin manufacturing milk price series is the standard on which the Federal order system determines Class I and II milk prices. The Minnesota-Wisconsin manufacturing milk price is related to the wholesale prices of butter, cheese, and nonfat dry milk. We calculate the price of fluid-eligible milk by weighting Class I and II prices by the proportion of fluid-eligible milk utilized as Class I and II.

The farm-level price of milk reflects both the relative proportion of milk produced as fluid and as manufacturing grades and their respective prices. The producer price of manufacturing milk is related to the wholesale prices of butter, cheese, and nonfat dry milk. We calculate the producer price of milk by weighting the prices of manufacturing and fluid-eligible milk by the proportion of milk produced as fluid-eligible and manufacturing grades.

Milk Manufacturing

The dairy submodel contains equations to predict supply, utilization, and prices for butter, cheese, nonfat dry milk, frozen milk products, fluid milk, and condensed and evaporated milk. It is hypothesized that the demand for milk to be processed into fluid, condensed, and evaporated milk and into frozen desserts will be satisfied prior to the allocation of milk to butter, cheese, and nonfat dry milk production. The volume of milk available for manufacturing (milk production

less that processed into fluid, condensed, and evaporated milk, into frozen milk products, and into milk consumed by calves) explains production of butter, cheese, and nonfat dry milk. Production of butter, cheese, and nonfat dry milk is also affected by their respective wholesale price-proxies reflecting the relative profitability of producing each of these products. Production of evaporated and condensed milk is related to the prices of fluid and condensed and evaporated milk. Imports and exports of dairy products are exogenous.

Retail prices of the six dairy products are expressed as a function of their respective wholesale price and variables that reflect marketing costs. Explicit econometric equations do not need to be specified either for the wholesale prices of cheese, nonfat dry milk, and butter or for the retail price of condensed and evaporated milk as these equations can be derived from specified production, demand, and stock relationships.

Commercial Demand

Commercial demand for dairy products consists of exports, domestic consumption, stocks, and Government purchases. Exports and military consumption are exogenous. Civilian consumption of each dairy product is related to its own real price, the real price of competing products, real disposable income, and population growth. Commercial stocks of butter, cheese, and nonfat dry milk are related to their respective wholesale prices and to production.

Government purchases (placements) of dairy products have generally been specified as linear functions of the wholesale price and the Government support price (*6*). Such functional relationships ignore the discontinuity in Government purchases when market clearing prices are above the designated support price.

We avoid this problem by computing Government purchases as the residual difference between supply and demand. Initially, a free-market clearing price is computed. This price is then compared with the price-support level, and if the free-market price is above the price-support level and below the release price, no action is taken. However, if the free-market price is below the price-support level, the market price is set equal to the price-support level, and the level of Government purchases is computed as the difference between supply and demand at the support price. A similar process is followed when the free-market price exceeds the release price for a particular dairy product.

Empirical Equations

We estimated the equation parameters of the dairy submodel using ordinary least squares. We selected three distinct time periods—1950-79, 1955-79, and 1960-79—for parameter estimation. The final set of equations selected represents the best set based on hypothesized parameter signs, significance of the parameter estimates, and the standard error of regression. We compared parameter estimates over the three estimation periods. When parameter estimates did not vary substantially over the three estimation periods, we included the equation using the longest data series in the submodel.

A few equations, while accurately predicting a particular variable over much of the estimation period, contained rather substantial errors for selected years. The most notable errors were for dairy cow additions during the 1965-71 period and dairy cow slaughter during the 1965-69 period. Dummy variables were included only after alternative specifications were explored and found inferior. Table 1 defines the variables contained in the submodel. Tables 2 through 8 report the parameter estimates.

The dairy cow additions and slaughter equations indicate that increases in cattle (utility cow and calf) prices and in feed costs reduce the number of dairy cows. An increase in feeding costs negatively affects milk production per cow. The stock of dairy cows on farms 2 years earlier was included in the dairy cow additions equation as a proxy for the available supply of replacements.

Production of butter and cheese was found to be significantly related to the wholesale prices of butter, cheese, and nonfat dry milk and to the quantity of milk available for manufacturing. Producer milk prices were significantly related to the wholesale prices of butter, cheese, and nonfat dry milk. Nonfat dry milk production was positively related to butter production, but negatively related to cheese production.

Per capita civilian disappearance of fluid milk is a function of the ratio of the retail price of fluid milk relative to the consumer price index (CPI) for nonalcoholic beverages and is a function of the ratio of the retail price of fluid milk relative to the price of nonfat dry milk. Increases in both variables significantly reduce civilian disappearance of fluid milk. A time trend captures the decline in consumer preferences for fluid milk relative to nonalcoholic beverages during the estimation period. Per capita disposable real income was dropped from the regression because it was not statistically significant.

Per capita civilian disappearance of nonfat dry milk declines as the price of nonfat dry milk increases relative to the price of fluid milk. Unlike per capita civilian disappearance of fluid milk, there is a fairly strong positive relationship between per capita consumption of nonfat dry milk and real per capita disposable income.

Per capita civilian disappearance of butter declines significantly as the ratio of the retail price of butter increases

Table 1—Dairy submodel variables

Variable	Definition
Endogenous:	
COWSNMC	Number of milk cows on farms, January 1, million head
COWKSMC	Number of milk cows slaughtered, million head
COWSEMC	Number of dairy cow replacements, million head
MILPF	Average price received by farmers for all milk sold to plants, dollars per cwt
MILECLOP	Effective Class I milk price paid by dealers, dollars per cwt
MILMWAT	Minnesota-Wisconsin manufacturing grade milk price, dollars per cwt
MILPPFEMAT	Average price received by farmers for fluid eligible milk, dollars per cwt
MILPPMAT	Average price received by farmers for manufacturing grade milk, dollars per cwt
MILBC	Quantity of milk fed to calves, billion pounds
MILAP	Total milk production, billion pounds
MILSPPLTS	Quantity of milk sold to plants and dealers, billion pounds
MILASFM	Quantity of milk produced eligible for fluid market, billion pounds
MILMFG	Quantity of milk available for manufacturing, billion pounds
MILSPFZ	Production of frozen dairy products, billion pounds of milk used
MILSPEC	Production of evaporated and condensed milk, billion pounds
MILSPECM	Production of evaporated and condensed milk, billion pounds of milk used
MILCCMC	Civilian disappearance of fluid milk plus cream, billion pounds
MILBUT	Wholesale price of Grade A butter, Chicago, cents per pound
MILAMCHEE	Wholesale price of American cheese at Wisconsin assembling points, 40-pound block, cents per pound
MILPWDR	Wholesale price index for nonfat dry milk, 1967 = 1.0
MILOMP	Minimum Federal order price for Class I milk, dollars per cwt
MILIR	Retail price index for fluid milk, 1967 = 1.0
MILIRIC	Retail price index for ice cream, 1967 = 1.0
MILCCFZ	Civilian disappearance of milk used in frozen dairy products, billion pounds
MILCCEC	Civilian disappearance of evaporated and condensed milk, billion pounds
MILIREV	Retail price index for evaporated milk, 1967 = 1.0
MILHTEV	Ending stocks of evaporated and condensed milk, billion pounds
MILSPND	Production of nonfat dry milk, billion pounds
MILCCND	Civilian disappearance of nonfat dry milk, billion pounds
MILHGND	Beginning USDA stocks of nonfat dry milk, billion pounds
MILHBND	Beginning commercial stocks of nonfat dry milk, billion pounds
MILGUND	USDA purchases of nonfat dry milk, billion pounds
CHESP	Production of cheese, billion pounds
CHECT	Civilian disappearance of cheese, billion pounds
CHEHB	Beginning commercial stocks of cheese, billion pounds
CHEHG	Beginning USDA stocks of American cheese, billion pounds
CHEGU	USDA purchases of American cheese, billion pounds
CHEIRAM	Retail price index of American cheese, 1967 = 1.0
BUTSP	Production of butter, billion pounds
BUTCC	Civilian disappearance of butter, billion pounds
BUTHB	Beginning commercial stocks of butter, billion pounds
BUTHG	Beginning USDA stocks of butter, billion pounds
BUTGU	USDA purchases of butter, billion pounds
BUTIR	Retail price index of butter, 1967 = 1.0
DARCPI	Retail price index of dairy products, 1967 = 1.0
DAIGP	Total cost of USDA dairy product purchases, million dollars
DAIFC	Cash receipts from milk sales, billion dollars
Exogenous:	
CATPFNF*	Price of utility cows, Omaha, dollars per cwt
CORPF*	Price received by farmers for corn, Oct.-Sept., dollars per bushel
BARPF*	Price received by farmers for barley, June-May, dollars per bushel
OATPF*	Price received by farmers for oats, June-May, dollars per bushel
SORPF*	Price received by farmers for grain sorghum, Oct.-Sept., dollars per bushel
WHEPF*	Price received by farmers for wheat, June-May, dollars per bushel
SOMPF*	Price of soybean meal, Decatur, 44 percent, dollars per cwt
CALPF*	Price received by farmers for calves, dollars per cwt
.TIME	Time trend 1950 = 50, 1951 = 51, and so forth
MILOOP	Federal order over order payments for Class I milk, dollars per cwt
BUTGG	USDA donations of butter, billion pounds
BUTDV	USDA unaccounted-for change in stocks of butter, billion pounds
.GASIR	Consumer price index for regular and premium gasoline, 1967 = 1.0
.YPD$	U.S. personal disposable income, billion dollars
MARIR*	Consumer price index for margarine, 1967 = 1.0
DUM_{ij}	Dummy variable, 19ij = 1.0
DUM_{ijkl}	Dummy variable, 19ij − 19kl = 1.0
MILMGND	USDA exports of nonfat dry milk, billion pounds
MILDVND	USDA unaccounted-for change in stocks of nonfat dry milk, billion pounds
CHEMX	Exports of cheese, billion pounds
CHEMI	Imports of cheese, billion pounds
CHECM	Military disappearance of cheese, billion pounds

Table 1—Dairy submodel variables (continued)

Variable	Definition
CHEGG	USDA donations of American cheese, billion pounds
CHEMG	USDA exports of cheese, billion pounds
CHEDV	USDA unaccounted-for change in stocks of American cheese, billion pounds
BUTMG	USDA exports of butter, billion pounds
BUTMX	Exports of butter, billion pounds
BUTMI	Imports of butter, billion pounds
BUTCM	Military disappearance of butter, billion pounds
MILCIDF	Historical difference between Federal order minimum Class I milk price and Minnesota-Wisconsin manufacturing grade price, dollars per cwt
MILPFDIF	Historical difference between average price received by farmers for fluid eligible milk and weighted Federal order price for fluid eligible milk, dollars per cwt
.WRHD	Dairy manufacturing industry wage rate, dollars per hour
.NPC	Total U.S. population, millions
.PCNAL*	Consumer price index for nonalcoholic beverages, 1967 = 1.0
.PC*	Consumer price index for all items, 1967 = 100
MILMIND	Imports of nonfat dry milk, billion pounds
MILMXND	Exports of nonfat dry milk, billion pounds
MILCMND	Military disappearance of nonfat dry milk, billion pounds
MILGGND	USDA donations of nonfat dry milk, billion pounds
MILSPPBUT	USDA purchase price of butter, dollars per cwt
MILNFDSPP	USDA purchase price of nonfat dry milk, dollars per cwt
MILCHCHSPP	USDA purchase price of American cheese, dollars per cwt
MILMIEC	Imports of evaporated and condensed milk, billion pounds
MILMXEC	Exports of evaporated and condensed milk, billion pounds
MILCMEC	Military disappearance of evaporated and condensed milk, billion pounds
MILMIFZ	Imports of frozen dairy products, billion pounds
MILCMFZ	Military disappearance of frozen dairy products, billion pounds
MILBCND	Nonfat dry milk fed to calves, billion pounds

*Denotes variables that are exogenous to the dairy submodel, but endogenously computed by other FAPSIM submodels.

relative to the retail price of margarine, but the disappearance of butter does not appear to be significantly affected by the level of real per capita disposable income. A time trend reflects reduced consumption of foods high in cholesterol. Beginning in 1978, the downward trend in civilian disappearance of butter seems to have leveled off somewhat.

Per capita civilian disappearance of cheese is a function of the ratio of the retail price of cheese relative to the all-item CPI and to real per capita disposable income. The retail price of meat was dropped from the equation because it was not statistically significant. However, the demand for cheese seems to have shifted upward in 1973, immediately after the large increase in meat prices. It appears that consumers significantly increased their demand for cheese following the large increase in meat prices in 1972-73 and did not reduce their demand for cheese after meat prices leveled off.

Validation Statistics

Various procedures have been proposed for validating econometric models. These procedures generally involve examining the statistical characteristics of individual equations, as well as examining the predictive ability of the entire system of equations. The equations comprising the dairy submodel seem to contain parameters of appropriate sign and magnitude. However, such characteristics do not ensure that the entire system of equations will accurately predict future events. Since future events are unknown, researchers have proposed that model predictions for historical periods be used to examine a model's predictive ability.

A variety of validation statistics have been proposed to determine the predictive adequacy of econometric models.[3] The most widely used include: the mean absolute relative error (MARE), Theil's U_1 and U_2 statistics, and turning point error (TPE). The MARE is widely used because of its ease in calculation and interpretation. It can be interpreted as the mean error of the model's estimate for a particular variable. If the MARE equals zero, the model's estimate for a particular variable exactly equals that variable's historical data. The MARE is independent of measurement units.

A drawback of the MARE is that it does not possess an upper limit. Thus, Theil's U_1 statistic was proposed as an alternative measure of a model's predictive ability. The value of this statistic equals zero if the model's estimates for a variable are exactly equal to that variable's historical data. The maximum value of Theil's U_1 statistic is 1, which will occur either when negative proportionality exists between the model's estimates and the historical data or the model always predicts a value of zero for nonzero historical values or when the model predicts nonzero values for historical values that are zero.

[3] See (5) and (7) for indepth discussions on historical validation of econometric models.

Table 2—Milk supply

Variable	Equation
COWSNMC(+1)	0.98 COWSNMC + COWSEMC − COWKSMC
COWKSMC	0.738171 + 0.326629 DUM6569 + 0.479213 DUM5758 − 0.149505 MILPF/FDD (2.41) (5.59) (6.21) (−3.50)
	+ 0.102808 COWSNMC + 0.501987 COWSEMC − 0.754813 MILPF/CATPFNF (2.85) (2.33) (−1.62)
	R^2 = 0.987
COWSEMC	0.203916 + 1.09718 MILPF(−1)/CALPF(−1) + 0.0841727 MILPF(−1)/FDD(−1) (0.52) (1.74) (1.41)
	+ 0.142653 COWSNMC(−2) − 0.318917 DUM6571 (18.82) (−6.02)
	R^2 = 0.961
$\frac{\text{MILAP}}{\text{(COWSNMC(+1)+COWSNMC)/2}}$	− 3.92481 + 0.135732 MILPF/FDD + 0.127848 · TIME (−2.61) (2.38) (2.83)
	+ 0.424017 MILAP(−1)/(COWSNMC + COWSNMC(−1))/2 (2.20)
	R^2 = 0.991
MILBC	− 0.381728 + 0.167949 COWSNMC (−5.87) (42.31)
	R^2 = 0.984
$\frac{\text{MILSPPLTS}}{\text{(MILAP − MILBC)}}$	− 1.73964 + 0.0717014 .TIME − 0.000473564 .TIME**2 (−17.00) (23.28) (−20.63)
	R^2 = 0.993
$\frac{\text{MILASFM}}{\text{MILSPPLTS}}$	− 0.0433665 + 1.02736 MILASFM(−1)/MILSPPLTS(−1) (−1.24) (38.61)
	+ 0.0236661 (MILPPFEMAT(−1) − MILPPMAT(−1)) (1.38)
	R^2 = 0.986
MILMFG	MILAP − MILBC − MILCCMC − MILSPFZ − MILSPECM
FDD	0.5563 CORPF(−1) + 0.0469 SORPF(−1) + 0.2565 OATPF(−1) + 0.0462 BARPF(−1)
	+ 0.0102 WHEPF(−1) + 0.0839 SOMPF(−1)

Note: Numbers in parentheses are Student-t values.

A more stringent test of the predictive ability of an econometric model is Theil's U_2 statistic. This statistic equals zero when the model's estimates for a particular variable exactly coincide with that variable's historical data. It equals 1 if the forecast error generated by the model for a variable equals the error generated when we assume that variable remains unchanged from the previous year. A value greater than 1 indicates that the model generates predictive errors exceeding those derived when we assume current-year values equal previous-year values.

Another measure of the ability of a model to predict turning points is the TPE statistic. Errors in predicting turning points stem from two sources. First, the model may predict a turning point in a variable when one did not occur. Second, the model may fail to predict a turning point when one did occur. The TPE measures the relative frequency of the total number of turning point errors.

The dairy-sector submodel was validated over the 1966-79 period.[4] In the validation run, historical values were used for all nondairy-sector variables contained in FAPSIM. The dairy-sector submodel generated values for lagged endogenous variables. As a result, model errors over the historical period stem from two sources. The first source is a result of

[4] A Gauss-Seidel algorithm is used to solve the model's system of simultaneous equations (*4*).

Table 3—Milk price

Variable	Equation
MILPPMAT	− 0.283616 + 0.0178284 MILBUT + 0.599078 MILPWDR (−1.31) (1.77) (3.15) + 0.0543683 MILAMCHEE (5.13) $R^2 = 0.999$
MILMWAT	− 0.226964 + 0.0114579 MILBUT + 0.449113 MILPWDR (−3.15) (3.34) (3.52) + 0.0663590 MILAMCHEE (9.31) $R^2 = 0.999$
MILOMP	MILCIDF + MILMWAT
MILECLOP	MILOOP + MILOMP
MILPPFEMAT	MILPFDIF + [(MILECLOP)(MILCCMC)(MILSPPLTS)/(MILAP − MILBC) + (MILMWAT)((MILASFM − MILCCMC)(MILSPPLTS))/(MILAP − MILBC)]/MILASFM
MILPF	[(MILPPFEMAT)(MILASFM) + (MILPPMAT)(MILSPPLTS − MILASFM)]/MILSPPLTS

Note: Numbers in parentheses are Student-t values.

Table 4—Butter sector

Variable	Equation
BUTSP	− 0.350572 + 1.22365 MILBUT/MILAMCHEE + 0.0116949 MILMFG (−1.30) (6.31) (2.40) − 0.152769 MILAMCHEE/MILPWDR + 0.153427 DUM74 (−2.42) (2.40) $R^2 = 0.926$
$\frac{\text{BUTCC}}{\text{.NPC}}$	0.0600122 − 0.00274512 BUTIR/MARIR + 0.00114400 DUM7879 − 0.00080432 DUM74 (9.17) (−2.46) (3.12) (−1.61) − 0.152247 .TIME/.NPC (−8.93) $R^2 = 0.869$
BUTIR	− 0.0858682 + 0.0130207 MILBUT + 0.0413876 .WRHD + 0.101378 .GASIR (−3.36) (16.24) (4.12) (2.95) $R^2 = 0.996$
BUTHB(+1)	0.0036095 + 0.0162062 BUTSP + 0.0156486 DUM7374 (0.32) (2.49) (2.49) $R^2 = 0.203$
MILBUT	$(-$ BUTSP + BUTCC + BUTHB(+1) − BUTHB + BUTMX + BUTCM − BUTMI + BUTHG(+1) − BUTHG$)^{-1}$
BUTHG(+1)	BUTSP − BUTCC + BUTHG − BUTHB(+1) + BUTHB − BUTMX − BUTCM + BUTMI
BUTGU	BUTHG(+1) − BUTHG − BUTGG + BUTMG − BUTDV

Note: Numbers in parentheses are Student-t values.

Table 5—Cheese sector

Variable	Equation
CHESP	− 6.07091 + 0.111475 MILMFG + 3.12002 MILAMCHEE/MILBUT (−3.74) (10.79) (3.74) + 0.0101392 MILAMCHEE/MILPWDR − 0.517856 DUM74 + 0.288983 DUM68 (0.60) (−3.22) (2.15) $R^2 = 0.966$
CHECT / .NPC	0.00307155 − 0.955747 CHEIRAM/.PC + 0.609481 .YPD$/(.NPC)(.PC) (1.11) (−2.02) (7.68) + 0.00368518 DUM7480 (6.90) $R^2 = 0.990$
CHEIRAM	0.0391632 + 0.0138097 MILAMCHEE + 0.0832134 .WRHD + 0.0832052 .GASIR (1.00) (4.20) (1.59) (1.13) $R^2 = 0.995$
CHEHB(+1)	− 0.139726 + 0.260058 CHEHB + 0.556479 CHESP (−3.23) (1.48) (3.06) $R^2 = 0.581$
MILAMCHEE	(− CHESP + CHECT + CHEHB(+1) − CHEHB + CHEMX + CHECM − CHEMI + CHEHG(+1) − CHEHG)$^{-1}$
CHEHG(+1)	CHESP − CHEHB(+1) − CHECT − CHEMX − CHECM + CHEMI + CHEHB + CHEHG
CHEGU	CHEHG(+1) − CHEHG + CHEGG + CHEMG − CHEDV

Note: Numbers in parentheses are Student-t values.

Table 6—Nonfat dry milk sector

Variable	Equation
MILSPND	0.220950 + 1.50162 BUTSP − 0.225588 CHESP (0.71) (8.62) (−4.44) $R^2 = 0.961$
MILCCND / .NPC	0.00667157 + 0.00140079 DUM73 − 0.00243915 MILPWDR/MILIR + 0.0515417 .YPD$/(.NPC)(.PC) (14.99) (5.07) (−10.95) (2.08) $R^2 = 0.937$
MILHBND(+1)	0.0420496 + 0.276756 MILSPND + 0.0647213 DUM74 (2.27) (2.35) (2.65) $R^2 = 0.301$
MILPWDR	(− MILSPND + MILCCND + MILHGND(+1) − MILHGND − MILMIND − MILHBND + MILMXND + MILBCND + MILHBND(+1) + MILCMND)$^{-1}$
MILHGND(+1)	MILCCND + MILSPND + MILHGND − MILBCND + MILHBND − MILMXND + MILMIND − MILHBND(+1) − MILCMND
MILGUND	MILHGND(+1) − MILHGND + MILGGND + MILMGND − MILDVND

Note: Numbers in parentheses are Student-t values.

Table 7—Evaporated and condensed milk sector

Variable	Equation
MILSPEC	8.54493 – 0.112500 .TIME + 0.939724 MILIREV/MILIR (33.12) (–16.89) (3.40) R^2 = 0.975
$\frac{\text{MILCCEC}}{\text{.NPC}}$	0.0230599 + 0.00121912 DUM6568 – 0.00241843 MILIREV/MILIR – 0.459281 .YPD$/(.NPC)(.PC) (13.12) (4.06) (–2.15) (–5.37) R^2 = 0.980
MILHTEV(+1)	– 0.0291461 + 0.0546571 DUM6667 + 0.0862268 MILSPEC (–1.82) (3.35) (9.68) R^2 = 0.862
MILIREV	(– MILSPEC + MILCCEC + MILHTEV(+1) – MILMIEC + MILMXEC + MILCMEC – MILHTEV)$^{-1}$
MILSPECM	0.313912 + 1.96209 MILSPEC (6.63) (75.60) R^2 = 0.997

Note: Numbers in parentheses are Student-t values.

Table 8—Frozen desserts and fluid milk sector

Variable	Equation
$\frac{\text{MILCCFZ}}{\text{.NPC}}$	0.0730505 – 1.90300 MILIRIC/.PC – 0.093076 .YPD$/(.NPC)(.PC) (7.28) (–3.46) (–0.61) R^2 = 0.740
MILIRIC	2.35231 + 0.335003 .WRHD + 0.0423319 MILECLOP – 0.0382222 .TIME (9.32) (5.50) (1.79) (–8.44) R^2 = 0.982
MILSPFZ	MILCMFZ – MILMIFZ + MILCCFZ
$\frac{\text{MILCCMC}}{\text{.NPC}}$	2.45628 – 0.0915642 MILIR/.PCNAL – 0.0470187 MILIR/MILPWDR – 6.02686 .TIME (10.67) (–7.86) (–2.54) (–9.75) R^2 = 0.960
MILIR	0.221189 + 0.0491676 .WRHD + 0.105076 MILECLOP (14.85) (3.37) (13.24) R^2 = 0.997
DARCPI	– 0.039374 + 0.671257 MILIR + 0.102841 BUTIR + 0.190153 CHEIRAM + 0.0775998 MILIRIC (–4.80) (39.59) (11.69) (14.60) (10.26) R^2 = 0.999
DAIGP	((BUTGU)(MILSPPBUT) + (CHEGU)(MILCHCHSPP) + (MILGUND) (MILNFDSPP)) .10
DAIFC	290.148 + 9.97787 (MILPF)(MILSPPLTS) (10.42)(282.07) R^2 = 0.999

Note: Numbers in parentheses are Student-t values.

the inability of the model's equations to exactly predict economic events in the dairy sector in any particular year. The second source stems from the model's inability to exactly predict past (lagged) values for dairy-sector variables.

Table 9 presents the validation statistics computed for the dairy-sector variables for the 1966-79 period.[5] Overall, the dairy-sector equations appear to predict with reasonable accuracy. Total cow numbers (COWSNMC) were predicted with an average error of less than 1 percent and with no turning point errors. Total milk production (MILAP) was predicted within about 1 percent. Over the 14-year (1966-79) period, the model predicted three turning points in milk production that did not occur. Two of those errors occurred in 1974 and 1975 when milk prices were increasing rapidly. However, as indicated by the MARE and by Theil's U statistics, the failure to predict such turning points did not lead to substantial prediction errors.

Milk prices are predicted with reasonable accuracy, as well as production, utilization, and prices of manufactured dairy products. Of the 44 variables, 27 are predicted within a 5-percent error on average over the 1966-79 period, and 26 have fewer than four turning point errors (table 9). Only seven variables have average errors exceeding 10 percent, and only five variables have Theil's U_2 statistics exceeding 1.0.

Commercial stocks of evaporated and condensed milk, nonfat dry milk, and butter were all predicted with an average

[5] The validation statistics presented in table 9 for milk production and price are similar to those obtained when the entire FAPSIM model was validated (*10*).

Table 9—Validation statistics, 1966-79

Variable	Mean absolute relative error	Theil U_1 statistic	Theil U_2 statistic	Turning point error[1]
	Percent			
COWSNMC	0.87	0.174	0.329	0.000
COWKSMC	2.58	.215	.445	.429
COWSEMC	3.17	.668	1.296	.286
MILPF	5.34	.332	.673	.143
MILECLOP	4.68	.311	.615	.214
MILMWAT	6.39	.344	.703	.143
MILPPFEMAT	5.31	.340	.697	.143
MILPPMAT	6.04	.327	.668	.143
MILBC	2.18	.394	.867	.143
MILAP	1.03	.320	.619	.214
MILSPPLTS	1.18	.315	.620	.214
MILASFM	1.86	.516	.819	.214
MILMFG	3.33	.203	.407	.286
MILSPFZ	1.45	.167	.319	.357
MILSPEC	3.08	.231	.424	.214
MILSPECM	3.12	.233	.426	.214
MILCCMC	1.95	.531	1.394	.429
MILBUT	6.64	.379	.942	.429
MILAMCHEE	7.36	.382	.790	.214
MILPWDR	4.56	.277	.497	.143
MILOMP	4.93	.327	.644	.286
MILIR	2.83	.217	.420	.143
MILIRIC	2.92	.180	.367	.143
MILCCFZ	1.45	.449	.862	.214
MILCCEC	2.64	.217	.437	.143
MILIREV	4.32	.221	.459	.214
MILHTEV	14.26	.241	.445	.286
MILSPND	9.08	.424	.743	.571
MILCCND	4.63	.238	.513	.286
MILHBND	27.33	.282	.486	.500
MILGUND	54.33	.304	.552	.357
CHESP	3.39	.268	.572	.071
CHECT	2.72	.250	.542	.071
CHEHB	9.17	.355	.598	.357
CHEGU	101.34	.569	1.420	.143
CHEIRAM	3.83	.247	.505	.143
BUTSP	6.28	.520	.951	.500
BUTCC	4.55	.505	1.113	.357
BUTHB	43.77	.315	.540	.500
BUTGU	50.86	.403	.790	.286
BUTIR	6.06	.382	.885	.071
DARCPI	3.06	.221	.450	.143
DAIFC	4.98	.336	.735	.214
DAIGP	47.69	.580	1.393	.214

[1] The number of turning point errors divided by 14, the total number of possible turning point errors.

error exceeding 10 percent. Such errors were not unexpected as commercial stocks of these dairy products are small relative to total production (generally less than 0.5 percent) and tend to be quite volatile. Because such stocks comprise only a small portion of the demand for these dairy products, sizable prediction errors in these variables do not generally result in substantial errors in other variables.

The three additional variables with MARE exceeding 10 percent were USDA purchases of cheese (CHEGU), butter (BUTGU), and nonfat dry milk (MILGUND). However, if 1979 is ignored, the MARE of USDA purchases of cheese declines from 101 to 34 percent and the MARE of USDA purchases of butter declines from 50 to 22 percent. The large overestimates of Government purchases of butter and cheese in 1979 stem from an overestimate of milk production coupled with an underestimate of fluid milk consumption. Both those prediction errors caused the model to overestimate butter and cheese production, which in turn caused substantial overestimates of USDA purchases of butter and cheese.

The Theil U_2 statistic and the TPE statistic suggest that the large errors predicted for USDA purchases of butter, cheese, and nonfat dry milk are somewhat misleading. First, the number of turning point errors are not substantial. Second, for both butter and nonfat dry milk, the model outperforms a no-change-from-previous-year forecast. Furthermore, such purchases were extremely volatile over the validation period and in many years were negligible. For example, USDA purchases of cheese ranged from less than 3.0 million pounds in 1973 to 148.0 million pounds in 1977. The MARE statistic will tend to be large in such circumstances as a 3.0-million-pound error in 1973 is treated as equivalent to a 148.0-million-pound error in 1977.

An additional validation test is to compare model predictions with actual data for periods not included in the estimation of model equations. Therefore, we performed a 1-year simulation for 1980. The model estimated milk prices and production with less than a 1-percent error. The only substantial error occurred in the model's estimate of USDA cheese purchases; it exceeded its actual value by 106.0 percent. Again, the residual nature of this variable was the cause of the large error. In 1980, the model overestimated cheese production by 5.0 percent, and it underestimated civilian consumption of cheese by 6.8 percent. Together, these two errors caused the large overestimate of USDA cheese purchases. This finding suggests that although the supply and utilization of dairy products may be estimated with reasonable error, the residual nature of dairy product purchases may still result in rather substantial errors in predictions for USDA purchases.

Overall, the model seemed to perform adequately over the 1966-79 validation period and in 1980. The model demonstrated an ability to generate reasonable and accurate forecasts for a period characterized by rapidly changing milk prices.

Analysis of Dairy Price Supports

In the remainder of this article, we use the dairy submodel and other submodels contained in FAPSIM to examine the effects of alternative dairy price-support options on the dairy sector and on other livestock and crops sectors. We explore these impacts by comparing FAPSIM model forecasts under two alternative assumptions of price-support levels. An initial FAPSIM model baseline for the 1981-85 period was generated under the assumption that manufactured milk would be supported at 75 percent of parity without semiannual adjustment. A second set of model forecasts for the 1981-85 period were generated under the assumption that manufactured milk would be supported at 65 percent of parity without semiannual adjustment. For this latter alternative, however, the price-support level was held at the April 1, 1981 level until it fell below 65 percent of parity. Table 10 presents the changes in dairy-sector variables forecasted by FAPSIM.

The results suggest that the farm price of milk (MILPF) would fall by about $0.11 per cwt in 1981 and by $0.83 per cwt in 1982. However, because of the assumption that the support level will not fall below the April 1, 1981 level, the full impact of the decline in support to 65 percent of parity does not occur until 1983. In 1983, the farm price of milk falls by $1.26 per cwt.

Farmers respond to the decline in support by increasing cow slaughter and by reducing the number of dairy cow replacements. By 1985, the model estimates that dairy cow numbers would fall by 0.22 million head. Total milk production would be about 3.0 billion pounds lower in 1985, resulting from the decline in support to 65 percent of parity.

The model indicates that civilian consumption of cheese (CHECT), butter (BUTCC), frozen milk products (MILCCFZ), and nonfat dry milk (MILCCND) would increase after the decline in support. Such increases coupled with reduced supplies would decrease USDA dairy product purchases. Consumption of evaporated and condensed milk declines slightly after the decline in support. This adjustment occurs because the retail price of fluid milk (MILIR) declines relative to the price of evaporated and condensed milk, thus reducing demand for evaporated and condensed milk.

USDA purchases of butter, cheese, and nonfat dry milk decline considerably. In 1983, the cost of USDA purchases of butter, cheese, and nonfat dry milk were estimated to fall by $870 million. Cash receipts to dairy farmers were estimated to fall by $1.8 billion in 1983.

Table 10—Impact on dairy-sector variables of changing from 75 to 65 percent of parity, 1981-85[1]

Variable	1981	1982	1983	1984	1985
COWSNMC	-0.006	-0.049	-0.114	-0.172	-0.219
COWKSMC	.006	.039	.040	.022	.011
COWSEMC	.000	-.003	-.026	-.038	-.040
MILPF	-.106	-.834	-1.258	-1.226	-1.234
MILECLOP	-.106	-.843	-1.253	-1.221	-1.227
MILMWAT	-.106	-.843	-1.253	-1.220	-1.227
MILPPFEMAT	-.104	-.832	-1.247	-1.205	-1.222
MILPPMAT	-.112	-.848	-1.374	-1.380	-1.432
MILBC	.000	-.001	-.008	-.020	-.029
MILAP	-.074	-.650	-1.563	-2.381	-3.034
MILSPPLTS	-.072	-.593	-1.476	-2.225	-2.838
MILASFM	-.060	-.505	-1.191	-1.447	-1.478
MILMFG	-.114	-.967	-1.777	-2.521	-3.130
MILSPFZ	.007	.048	.067	.062	.059
MILSPEC	.000	-.001	-.003	-.003	-.002
MILSPECM	.000	-.002	-.006	-.006	-.004
MILCCMC	.034	.273	1.60	.103	.034
MILBUT	-1.690	-10.790	-23.190	-25.380	-28.630
MILAMCCHEE	-1.000	-8.880	-10.415	-9.170	-8.139
MILPWDR	-.045	-.228	-.660	-.716	.799
MILOMP	-.106	-.843	-1.253	-1.221	-1.227
MILIR	-.011	-.089	-.131	-.128	-.129
MILIRIC	-.004	-.036	-.053	-.051	-.052
MILCCFZ	.007	.048	.067	.062	.059
MILCCEC	.000	-.002	-.002	-.002	-.002
MILIREV	-.019	-.156	-.241	-.239	-.244
MILHTEV	.000	.000	.000	.000	.000
MILSPND	-.012	-.011	-.228	-.264	-.302
MILCCND	.005	.023	.088	.095	.104
MILHBND	.000	-.001	-.008	-.009	-.011
MILGUND	-.016	-.035	-.315	-.365	-.411
CHESP	.000	-.085	.045	.004	-.023
CHECT	.011	.093	.101	.083	.070
CHEHB	.000	-.004	.001	.000	-.002
CHEGU	-.012	-.173	-.061	-.079	-.072
CHEIRAM	-.014	-.123	-.144	-.127	-.113
BUTSP	-.008	-.021	-.144	-.157	-.205
BUTCC	.005	.030	.058	.058	.060
BUTHB	.000	.000	-.004	-.005	-.006
BUTGU	-.013	-.051	-.200	-.233	-.264
BUTIR	-.022	-.140	-.302	-.330	-.373
DARCPI	-.013	-.100	-.151	-.148	-.150
DAIFC	-.143	-1.141	-1.819	-1.937	-2.127
DAIGP	-66.21	-440.22	-869.66	-1,097.19	-1,359.91

[1] Change in respective variable predicted by FAPSIM after the price-support level was reduced to 65 percent of parity.

The multicommodity nature of FAPSIM enables one to examine the impacts of a policy change on all agricultural commodity sectors. Because the above policy change affects livestock production and the demand for feed, sizable adjustments may occur in both the beef and veal and the feed-grain sectors. FAPSIM predicts that the price of corn would fall by 3.0 cents per bushel in 1985. Similar declines were estimated for sorghum and barley. The price of oats and soybeans declined by 8.0 cents per bushel in 1985. The larger decline in the price of oats is expected because of the high proportion consumed by dairy animals. The model predicts that the price of beef cattle would change by less than $1.00 per cwt as a result of changing the price-support level to 65 percent of parity.

Although not large, these predicted changes in crop prices suggest that if researchers fail to allow for feedback among the crops, livestock, and dairy sectors when analyzing changes in dairy policies, sizable errors may occur. To quantify the potential magnitudes of such errors, we simulated the 65-percent-of-parity scenario under the assumption that nondairy-sector variables remained at the levels predicted under the 75-percent-of-parity option. Table 11 contains the percentage errors in adjustment resulting from assuming no feedback among the crops, livestock, and dairy sectors.

Table 11 suggests that treating the dairy sector in isolation would result in moderate errors. For example, failure to allow for feedback among the crops, livestock, and dairy sectors would result in about a 10-percent error in predicting the adjustment in milk production during the 1981-85 period. Milk production would have been estimated to decline by an additional 0.4 billion pounds in 1985 under the assumption that the change in price-support policy would

Table 11—Estimated error in adjustment resulting from assumption of no feedback among the crops, beef and veal, and dairy sectors, 1981-85[1]

Variable	1981	1982	1983	1984	1985
	Percent				
COWSNMC	-7.50	-8.16	-9.65	-9.88	-11.87
COWKSMC	.00	10.26	12.50	13.64	45.45
COWSEMC	.00	-7.50	-7.69	-7.89	-10.00
MILPF	.00	.00	2.15	4.40	.24
MILECLOP	.00	.00	2.23	4.34	.00
MILMWAT	.00	.00	2.23	4.34	.00
MILPPFEMAT	.00	.00	2.25	4.56	.25
MILPPMAT	.00	.00	1.60	3.19	.00
MILBC	.00	.00	-12.50	-5.00	-10.34
MILAP	-9.46	-7.85	-9.60	-10.92	-13.12
MILSPPLTS	-8.33	-8.26	-9.62	-10.92	-13.00
MILASFM	-10.00	-8.12	-9.99	-13.20	-18.24
MILMFG	-7.02	-6.41	-8.16	-9.36	-12.97
MILSPFZ	.00	8.33	5.97	1.61	6.78
MILSPEC	.00	100.00	150.00	100.00	100.00
MILSPECM	.00	100.00	150.00	100.00	100.00
MILCCMC	-2.94	1.47	-8.13	-27.18	11.76
MILBUT	.00	.00	.00	.00	.00
MILAMCHEE	.00	.00	3.98	8.83	.00
MILPWDR	.00	.00	.00	.00	.00
MILOMP	.00	.00	2.23	4.34	.00
MILIR	.00	.00	2.29	4.69	.00
MILIRIC	.00	.00	1.89	3.92	.00
MILCCFZ	.00	8.33	5.97	1.61	6.78
MILCCEC	.00	100.00	150.00	100.00	100.00
MILIREV	.00	1.92	3.73	6.69	2.46
MILHTEV	.00	.00	.00	.00	.00
MILSPND	.00	.00	-3.51	-5.68	1.32
MILCCND	.00	.00	1.14	2.11	.00
MILHBNC	.00	.00	-12.50	-11.11	.00
MILGUND	.00	2.86	-2.86	-4.38	.73
CHESP	.00	-8.24	-15.56	-250.00	-195.65
CHECT	.00	-3.23	-6.93	-10.84	-2.86
CHEHB	.00	-25.00	.00	.00	-100.00
CHEGU	.00	-2.31	.00	.00	-56.94
CHEIRAM	.00	.00	4.17	8.66	.00
BUTSP	.00	-4.76	-4.86	-6.29	-1.95
BUTCC	.00	-6.67	-1.72	-1.72	-1.67
BUTHB	.00	.00	.00	.00	.00
BUTGU	.00	.00	-2.50	-4.29	-1.52
BUTIR	.00	.00	.00	.00	.00
DARCPI	.00	.00	1.99	2.70	.00
DAIFC	.00	-.61	.71	1.34	-3.10
DAIGP	-.77	-1.16	-1.83	-3.10	-5.52

[1] Estimated percentage error in respective variable resulting from assumption of no feedback.

not have affected crop and livestock prices. This additional adjustment compares with an estimated total adjustment in milk production of 3.0 billion pounds.

The level of milk prices does not seem substantially affected by assuming no feedback among the crops, livestock, and dairy sectors. The maximum error in estimated adjustment was 4.4 percent. However, the Government's price-support operations through purchases of dairy products largely ensure that large errors in predicting the adjustment in milk prices will not occur.

However, USDA purchases of dairy products could differ substantially because of the error in predicting the adjustment in milk production. In 1985, failure to allow for feedback would result in a 5.5-percent underestimate of the adjustment in USDA outlays for purchases of dairy products, which amounts to an underestimate of $75 million.

Conclusions

Mounting Government surpluses of manufactured dairy products and recent substantial Federal budget outlays for dairy price supports have renewed debate on the Government's role in the U.S. dairy industry. A variety of proposals have been formulated by policymakers, farmer groups, and the dairy industry to reduce the Government's role in milk

pricing and marketing. The complexity of the dairy industry requires that a formal analytical framework be developed so that the potential impacts of alternative proposals on dairy farmers, milk processing firms, and consumers can be analyzed and quantified.

The dairy submodel described here explicitly recognizes the role of the Government in supporting milk prices and marketing. Furthermore, the model captures the interrelationships among dairy products at both processing and consumer levels.

The dairy-sector submodel has been integrated into USDA's FAPSIM. FAPSIM estimates a simultaneous price-quantity equilibrium solution for a set of individual commodity models for beef, pork, dairy, chickens, eggs, turkeys, corn, oats, barley, grain sorghum, wheat, soybeans, and cotton. FAPSIM can be used to explore the impacts of changes in dairy policies on crop and livestock producers as well as the impacts of changes in nondairy-sector variables (for example crop exports) on milk prices and production and on Government purchases of dairy products.

The model suggests that reducing the price-support level on manufacturing milk from 75 to 65 percent of parity would cause the farm-level price of milk to fall $0.83 per cwt in 1982 and $1.26 per cwt in 1983. Total milk production would be about 3.0 billion pounds lower in 1985, and USDA outlays for purchases of dairy products would be about $1.4 billion lower in 1985.

Failure to allow for feedback among the dairy, beef, and crops sectors results in an overestimate of the production adjustment that would occur as a result of reducing the support level to 65 percent of parity. The magnitude of error is below 10 percent for most major dairy-sector variables such as milk production, prices, and Government outlays. Failure to allow for feedback (solving a dairy submodel in isolation) among the dairy, beef, and crops sectors appears not to cause sizable errors in predicted adjustment. Nevertheless, integrating a dairy-sector submodel with other commodity models increases the level of precision in predicting adjustment within the dairy sector. Also, an integrated model permits us to examine the impacts of dairy-sector adjustment on other agricultural commodity sectors as well as to examine the effects of shocks in nondairy-sector variables on milk prices and production and on Government outlays.

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The Demand for Food Consumed at Home and Away from Home

By R. McFall Lamm, Jr.*

Abstract

Over the last 20 years, consumers have spent a declining portion of their income on food for consumption at home, while the share of income spent on meals purchased at restaurants, cafeterias, and fast-food chains has held constant. This article attempts to explain this phenomenon by estimating a 3-equation translog system of quarterly consumer demand for food consumed at home, purchased meals, and nonfood items. An explicitly additive, nonlinear, nonhomothetic translog system is found to be the best representation. Results indicate that rising consumer incomes rather than changing relative prices are the principal reason consumers are eating away from home more often.

Keywords

Consumer food demand, translog system, dynamic model

A significant economic trend in recent decades is the declining share of consumer expenditures on food purchased for consumption at home. Per capita expenditures for at-home consumption fell steadily from 16.9 percent of all expenditures in 1960 to 13.2 percent in 1980. This drop occurred while the share of consumer expenditures on meals purchased at restaurants, cafeterias, and fast-food chains remained constant at about 4.0 percent. In contrast, the nonfood share of all consumer expenditures rose from 79.1 percent in 1960 to 82.8 percent in 1980. Hence, nonfood consumption has become more important relative to food consumption, and the consumption of purchased meals has become more important relative to food consumed at home.

Few researchers have attempted to explain why the budget share of food purchased for consumption at home has declined relative to away-from-home consumption. In their 1970 study, Houthakker and Taylor (*7*) did analyze the demand for food consumed at home and away from home; but, the recent systems work by Brown and Heien (*1*), Christensen and Manser (*3*, *4*), and Manser (*9*) focuses only on at-home food demand.[1] Furthermore, these studies consider only annual consumption patterns. Although annual data can be used to explain why expenditures for food consumed at home declined relative to food purchased away from home, policymakers and forecasters are also interested in consumer demand over shorter periods.

In this article, I examine the nature of quarterly demand for purchased meals and for food consumed at home by using a three-equation model of consumer demand. I consider three aggregate goods: meals purchased away from home, food purchased for consumption at home, and nonfood items. The methodology used requires estimation of a family of competing translog demand functions. I find an explicitly additive, nonlinear, nonhomothetic form to be the best system representation. I then derive impact, interim, and total multiplier elasticities and review the implications of the results. My major conclusion is that rising consumer income is the primary variable that explains why the consumption of purchased meals has become more important relative to food consumed at home.

The Model

Christensen, Jorgenson, and Lau (*2*) proposed the translog utility function as a second-order approximation to allow tests of different assumptions normally imposed on consumer demand systems. The indirect form of the translog utility function is written as:

$$\ln U = \alpha_0 + \sum_i \alpha_i p_i^* + \frac{1}{2} \sum_i \sum_j \beta_{ij} p_i^* p_j^* \tag{1}$$

Maximization of this equation subject to the budget constraint leads to "share" equations of the form:

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[1] Italicized numbers in parentheses refer to items in the References at the end of this article.

$$w_i = \frac{\alpha_i + \Sigma \beta_{ij} p_i^*}{\Sigma \alpha_j + \Sigma\Sigma \beta_{ij} p_j^*} \qquad i = 1, ..., I \tag{2}$$

where $w_i = p_i x_i / m$ (the budget share); $p_i^* = \ln(p_i/m)$; p_i is price; x_i is consumption; m is total expenditure; and α_i, β_{ij} $\forall i, j$ are parameters. Multiplying through each side by m/p_i gives demand equations which are neither additive nor homothetic.[2]

Phlips (*10*), Manser (*9*), and other consumption analysts have criticized static demand systems because they neglect the influence of habit formation. This would seem to be a particularly important aspect of food consumption. Manser proposed a dynamic version of the indirect utility function to incorporate habit formation by defining the α_i as a linear function of lagged consumption. This specification allows interaction between prices, total expenditures, and lagged consumption, and is written as:

$$\ln U_t = \alpha_0 + \sum_i \phi_i p_{it}^* + \sum_i \delta_i x_{it-1} p_{it}^* + \frac{1}{2} \sum_i \sum_j \beta_{ij} p_{it}^* p_{jt} \tag{3}$$

It preserves the general characteristics of the translog approximation and yields budget equations of the form:

$$w_{it} = \frac{\phi_i + \delta_i x_{it-1} + \Sigma \beta_{ij} p_{it}^*}{-1 + \Sigma\Sigma \beta_{ij} p_{jt}^*} \qquad \begin{matrix} i = 1, ..., I \\ t = 1, ..., T \end{matrix} \tag{4}$$

where the normalization $\Sigma\phi_j + \Sigma \delta_j x_{jt-1} = -1$ is imposed to assure that budget shares sum to unity. Importantly, from these share equations (*6*), impact, interim, and total multipliers (or elasticities) can be derived straightforwardly. This property is crucial for interpreting the full implications of any set of dynamic demand functions.

Empirical Implementation

Because all the parameters of a *k* equation translog demand system can be derived from estimating any *k* - 1 equations and because the system variance-covariance matrix is singular, only the budget share equations for food consumed at home and for purchased meals need to be estimated. The stochastic system of interest is then:

$$w_{1t} = \frac{a_1 + d_1 x_{1t-1} + b_{11} p_{1t}^* + b_{12} p_{2t}^* + b_{13} p_{3t}^*}{-1 + \Sigma b_{1j} p_{1t}^* + \Sigma b_{2j} p_{2t}^* + \Sigma b_{3j} p_{3t}^*} + e_{1t} \tag{5}$$

$$w_{2t} = \frac{a_2 + d_2 x_{2t-1} + b_{12} p_{1t}^* + b_{22} p_{2t}^* + b_{23} p_{3t}^*}{-1 + \Sigma b_{1j} p_{1t}^* + \Sigma b_{2j} p_2^* + \Sigma b_{3j} p_3^*} + e_{2t} \tag{6}$$

where symmetry ($b_{ij} = b_{ji}$ $\forall i,j$) and the normalizations, $a_1 + a_2 + a_3 = -1$ and $\Sigma d_i x_{it-1} = 0$, are imposed on the general translog form.[3] Equation (5) is the budget share equation for food consumed at home, and equation (6) is the budget share equation for purchased meals. The subscripts 1, 2, and 3 denote food consumed at home, purchased meals, and nonfood items, respectively. Each equation represents a general, nonhomothetic, nonadditive utility function which allows for habit formation.

By the imposition of restrictions on equations in demand systems, special cases of the utility function are implied. For the indirect translog function, those cases of greatest interest include explicit additivity (imposed using $b_{ij} = 0$, $i \neq j$); homogeneity (imposed with $\Sigma b_{ij} = 0$ $\forall i$); and the absence of habit formation (introduced by setting $d_i = 0$ $\forall i$). As long as equations (5) and (6) can be estimated, these restrictions can be tested explicitly as nested maintained hypotheses. This is the approach Manser used when choosing among alternative models which are special cases of the general translog system.

In practice, it is difficult to estimate equations (5) and (6); the large number of parameters, nonlinearity, and the probability of collinearity between e_1 and e_2 complicate matters. Christensen, Jorgenson, and Lau estimated a three-equation translog system using Malinvaud's (*8*) maximum likelihood estimator. Christensen and Manser (*3*) and Manser (*9*) used the nonlinear, iterative Zellner (*12*) estimation procedure (which converges to maximum likelihood estimators) to estimate a four-equation translog system. Both these studies utilized annual data which generally contain fewer measurement errors than do the quarterly data I consider here and, consequently, they were easier to estimate.

Estimation Results

I attempted to estimate equations (5) and (6) using the nonlinear, iterative estimation technique proposed by Gallant (*5*). The estimation algorithm is contained as part of the Statistical Analysis System (*11*) and uses the modified Gauss-Newton iterative approach to solve for estimators. It allows restrictions to be imposed through parameter definition. Even with a large range of possible starting values, conver-

[2] The literature on translog demand systems is well developed (*2*, *3*). The indirect utility function is used in lieu of the direct function because elasticities are easily obtained from budget share equations.

[3] The symmetry restriction is testable, but it requires significantly increasing the number of parameters contained in the model. The normalizations facilitate estimation.

gence could not be attained for the general equations. However, attempts to estimate most of the restricted forms of the system were successful.[4]

Table 1 presents estimation results. On the basis of the asymptotic standard errors, most parameters are highly significant statistically and of appropriate magnitude.[5] The calculated error sums of squares for each equation differ significantly. The explicit additivity restriction with habit formation gives the best fit for both equations; the error sums of squares are $0.32\ 10^{-5}$ and $0.41\ 10^{-5}$, respectively. Imposing homogeneity with habit formation gives the second best fit with error sums of squares of $2.58\ 10^{-5}$ and $0.69\ 10^{-6}$.

[4] Data on expenditure shares, prices (measured by the appropriate expenditure class deflator), and total expenditures are from the U.S. Department of Commerce. One can obtain consumption series by dividing total expenditures in each class by the expenditure class deflator. The sample consists of 83 observations covering the period from 1960 I to 1980 III. The food-consumed-at-home variables are defined as the Commerce food-consumed-off-premises series, whereas the purchased meals variable is defined as the Commerce food-consumed-on-premises series.

[5] Autocorrelation may be an important, but neglected, consideration.

Given explicit additivity and habit formation, one can test whether homogeneity and no habit formation are suitable restrictions using likelihood ratios. Table 2 presents the appropriate chi-square test statistics and the critical chi-square values at the 99-percent confidence level. In both instances, further restriction of the explicit additive form with habit formation is rejected with more than 99-percent confidence. It is also possible to test whether additional restrictions on the homogeneous system with habit formation are acceptable. Again, the imposition of no habit formation, explicit additivity, and explicit additivity without habit formation are rejected with more than 99-percent confidence.

This process reduces the model selection problem to a choice between the explicit additive system with habit formation and the purely homogeneous system with habit formation. Based on the error sum of squares, the former is preferred on the basis of fit. More information can be generated if dynamic simulations of the system are performed and if the resulting percentage root mean square errors (RMSE) and mean absolute errors (MAE) are computed.[6] Table 3 presents

[6] The Gauss-Seidel method for solving nonlinear systems is utilized. The nonlinear simulation algorithm is part of the Statistical Analysis System. Actual lagged endogenous variables are used as starting values for each simulation.

Table 1—Nonlinear, iterative Zellner estimates for various forms of the indirect translog utility function[1]

Parameter	Explicit additivity, habit formation	Explicit additivity, habit formation, homogeneity	Explicit additivity, homogeneity	Homogeneity, habit formation	Homogeneity
a_1	-0.663 (.071)	-0.319 (.011)	-0.146 (.001)	-0.302 (.010)	-0.150 (.001)
a_2	-.195 (.023)	-.036 (.001)	-.040 (.000)	-.018 (.002)	-.042 (.000)
d_1	$-.118\ 10^{-3}$ $(.016\ 10^{-3})$	$.379\ 10^{-3}$ $(.024\ 10^{-3})$		$.336\ 10^{-3}$ $(.022\ 10^{-3})$	
d_2	$-.164\ 10^{-3}$ $(.029\ 10^{-3})$	$-.032\ 10^{-3}$ $(.010\ 10^{-3})$		$-.154\ 10^{-3}$ $(.019\ 10^{-3})$	
b_{11}	-.078 (.008)			.061 (.009)	.086 (.011)
b_{12}				-.016 (.009)	.014 (.003)
b_{22}	-.024 (.003)			.027 (.003)	-.017 (.002)
b_{33}	.054 (.022)				
Σe_{1t}^2	$.32\ 10^{-5}$	$3.53\ 10^{-5}$	$12.20\ 10^{-5}$	$2.58\ 10^{-5}$	$6.89\ 10^{-5}$
Σe_{2t}^2	$.41\ 10^{-6}$	$1.47\ 10^{-6}$	$1.73\ 10^{-6}$	$.69\ 10^{-6}$	$2.89\ 10^{-6}$

Blanks indicate not applicable.

[1] Asymptotic standard errors are presented in parentheses. Symmetry is imposed for all models. For additivity, $b_{12} = 0$; for homogeneity, $b_{11} + b_{12} + b_{13} = 0$ and $b_{12} + b_{22} + b_{23} = 0$ ($b_{11} + b_{12}$ replaces b_{13} and $b_{12} + b_{22}$ replaces b_{23} in estimation); and the absence of habit formation requires $d_1 = d_2 = 0$.

Table 2—Test statistics for alternative restrictions on the general translog form

Restriction	Degrees of freedom	χ^2	$\chi^2 0.005$
	Given explicit additivity and habit formation		
Homogeneity	3	295.8	12.84
Homogeneity, no habit formation	5	421.9	16.75
	Given homogeneity and habit formation		
No habit formation	2	148.0	10.60
Explicit additivity	3	81.5	12.84
Explicit additivity, no habit formation	5	207.7	16.75

Table 3—Comparisons of fit: Explicit additivity with habit formation versus homogeneity with habit formation

Budget share	Explicit additivity		Homogeneity	
	RMSE	MAE	RMSE	MAE
	Percent			
Food consumed at home	1.21	0.91	3.29	2.44
Purchased meals	1.44	.89	1.97	1.49
Nonfood items	.22	.16	.62	.45

the resulting summary statistics. For all three budget shares, the explicit additive form with habit formation performs best in terms of predictive ability. Hence, given a choice between competing restrictions, the imposition of explicit additivity is more reasonable.

Implications

Assuming explicit additivity with habit formation as the best available translog approximation to consumer preferences, exploring the implications of the estimates is worthwhile. It can be shown that the direct price and expenditure elasticities take the form:[7]

$$\frac{p_i}{x_i}\frac{\partial x_i}{\partial p_i} = -1 + \frac{b_{ii}/w_i - b_{ii}}{-1 + \Sigma b_{jj}p_j^*} \qquad i = 1, ..., I \qquad (7)$$

$$\frac{m}{x_i}\frac{\partial x_i}{\partial m} = 1 + \frac{-b_{ii}/w_i + \Sigma b_{ii}}{-1 + \Sigma b_{jj}p_j^*} \qquad i = 1, ..., I \qquad (8)$$

Table 4 presents estimates of these elasticities for each commodity, evaluated at mean exogenous values for selected years. Current-quarter demand for food consumed at home and for purchased meals is highly inelastic, both with respect to price and to total food expenditure. In contrast, the demand for nonfood items is both price and expenditure-elastic.

The results are generally consistent with prior expectations; the demand for food is traditionally assumed to be price- and income-inelastic. But, it is usually presumed that the demand for purchased meals is more price- and income-elastic than the demand for food consumed at home; purchased meals are less necessary and more of a luxury than are meals at home. For this reason, the initial findings are somewhat puzzling. When the dynamic implications of the model are fully considered, however, one finds the demand for purchased meals is more elastic with respect to price and to total expenditure than is the demand for food consumed at home.

To show the dynamic implications of the model, we must solve equations (5) and (6) for x_i using $w_i = p_i x_i$ and we must substitute the resulting values sequentially for x_{it-j}. Computing the price and income elasticities at each stage of this process with respect to changes $t - j$ periods ago leads to the general expressions:

$$\frac{p_{it-n}}{x_{it}}\frac{\partial x_{it}}{\partial p_{it-n}} = \eta_{iit-n} \prod_{k=0}^{n} \frac{d_i x_{it-k-1}}{w_{it-k}(-1 + \Sigma b_{jj}p_{jt-n}^*)} \qquad (9)$$

$$\frac{m_{t-n}}{x_{it}}\frac{\partial x_{it}}{\partial m_{t-n}} = \eta_{imt-n} \prod_{k=0}^{n} \frac{d_i x_{it-k-1}}{w_{it-k}(-1 + \Sigma b_{jj}p_{jt-n}^*)} \qquad (10)$$

where: $\eta_{iit-n} = \frac{p_{it-n}}{x_{it-n}}\frac{\partial x_i}{\partial p_{it-n}}$

and $\eta_{imt-n} = \frac{m_{nt-n}}{x_{it-n}}\frac{\partial x_{it-n}}{\partial m_{it-n}}$

[7] A mathematical appendix illustrating the derivation of these expressions as well as equations (*9*) and (*10*) is available from the author.

Table 4—Direct price and expenditure elasticities, selected years

Year	Price elasticity			Expenditure elasticity		
	Food consumed at home	Purchased meals	Nonfood items	Food consumed at home	Purchased meals	Nonfood items
	Percent					
1960	-0.38	-0.10	-1.02	0.34	0.11	1.03
1965	-.30	-.11	-1.02	.25	.13	1.03
1970	-.26	-.08	-1.02	.21	.10	1.03
1975	-.25	-.13	-1.02	.20	.14	1.03
1980	-.16	-.11	-1.02	.11	.12	1.03

These are the interim elasticities for price and total expenditures, respectively.[8] Expression (9) gives the percentage impact on consumption this quarter resulting from a 1-percent increase in price n quarters ago. Similarly, expression (10) gives the impact on consumption this quarter resulting from a 1-percent increase in total expenditures n quarters ago.

Table 5 presents calculated, mean sample, interim elasticities for food consumed at home, purchased meals, and nonfood items over 8 quarters as well as the total multiplier elasticities obtained by summing all interim multipliers over 20 quarters (after which additional quantity impacts converge to approximately zero). The total multiplier elasticities represent the ultimate effect on consumption of a 1-percent increase in prices or in total expenditures many quarters ago. Clearly, the longrun demand for food consumed at home is less price- and expenditure-elastic than is the demand for purchased meals; total price and expenditure elasticities are −0.630 and 0.507 for food consumed at home and −0.701 and 0.995 for purchased meals. This finding is consistent with traditional theory. In addition, the longrun demand for nonfood items is more elastic with respect to both price and expenditure.

The evidence presented in table 5 further suggests that the effects of changes in own price or expenditures quickly affect food consumption at home, whereas the effects of changes in own price or expenditures for purchased meals are felt only after many quarters. Thus, over two or three quarters, increases in disposable income will have a greater effect on food consumed at home than on purchased meals. Similarly, price changes in grocery stores have a larger shortrun impact on food consumption at home, substantially more than the effect of changes in purchased meal prices on food consumption away from home. This may simply reflect the fact that lunches during work days or food consumed while traveling must generally be purchased. In the long run, however, adjustment occurs, and the amount of food purchased in grocery stores for home consumption is less sensitive than is the consumption of purchased meals to price and expenditure changes.

Table 5—Interim price and expenditure elasticities for food consumed at home, purchased meals, and nonfood items[1]

Lag	Food consumed at home		Purchased meals		Nonfood items	
	Price	Total expenditure	Price	Total expenditure	Price	Total expenditure
	Percent					
0	-0.255	0.206	-0.075	0.114	-1.020	1.186
1	-.149	.120	-.067	.102	.192	-.179
2	-.089	.071	-.060	.092	-.023	.028
3	-.054	.043	-.055	.083	.003	-.005
4	-.033	.027	-.050	.076	-.001	.001
5	-.021	.017	-.046	.070	.000	-.000
6	-.013	.010	-.043	.064	-.000	.000
7	-.008	.007	-.039	.059	.000	-.000
8	-.005	.004	-.036	.055	-.000	.000
Total	-.630	.507	-.701	.995	-.888	1.031

[1] Evaluated at mean sample levels. Total multipliers are 20-quarter sums of interim multipliers.

Conclusion

I have fitted indirect translog budget share equations for a three-good aggregate system using quarterly data. An explicitly additive, dynamic form provides the best approxima-

[8] The terms impact, interim, and total multiplier elasticities, as used here, are analogous to Goldberger's original usage, but each is expressed as a unit-free elasticity.

tion to consumer behavior. Shortrun demand for food consumed at home and for purchased meals is highly inelastic, whereas shortrun demand for nonfood items is elastic. The longrun demand both for foods consumed at home and for purchased meals is determined to be inelastic, but less so than the shortrun demand. The demand for food consumed at home is also somewhat more inelastic than that for purchased meals, which confirms prior expectations.

Prices for food consumed at home and for purchased meals have increased at similar rates over the last two decades, implying little relative price change. However, per capita consumer expenditures on all items increased about 13 percent per year over the same period. Thus, rising consumer incomes are the primary reason that consumption of purchased meals has increased relative to consumption of food at home. Consequently, the purchased meals share of the consumer's budget has substantially increased relative to the share of consumers' at-home food expenditures.

These findings have important implications for the food-retailing industry as well as for the restaurant and fast-food trade. Rising consumer incomes and increased expenditures signal a continuation of the trend toward consumption of purchased meals relative to at-home food consumption. Recent efforts by retail food chains to offer on-premises food services in grocery stores (for example, delicatessens, instore fast-food service, and small restaurants) suggest industry recognition of this fact.

Other developments suggest an acceleration towards increased consumption of purchased meals. In particular, recent policy proposals to reduce minimum wages for individuals under 18 would benefit restaurants, cafeterias, and the fast-food trade more than it would benefit food retailers. Grocery chains rely more on higher wage, unionized labor, whereas most workers in restaurants, cafeterias, and fast-food establishments receive the minimum wage. Hence, new legislation would likely lower relative prices for purchased meals as reduced labor costs are passed through to consumers. This would have a longrun positive effect on the consumption of purchased meals.

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Applying Principal Components Regression Analysis to Time Series Demand Estimation

By Luis R. Sanint*

Abstract

Demand functions for rice in Colombia and Venezuela, estimated by means of ordinary least squares, were unsatisfactory because of problems with multicollinearity. An alternative approach, principal components regression, was tried. Results showed that principal components regression estimates were more consistent with theoretical expectations and were statistically more significant. The cost of these gains was that the coefficients were biased. However, the mean-square-error tests indicated that the reduction in variance outweighed the loss due to bias.

Keywords

Principal components regression, ordinary least squares, time series demand estimation

The problem of multicollinearity occurs frequently in time series analysis. A number of statistical tools have been proposed to mitigate multicollinearity, and researchers have studied their statistical properties. Principal components regression (PC-OLS) is one technique proposed for use when ordinary-least-squares (OLS) parameter estimates are affected by multicollinearity. But, the conceptual problems that arise from applying alternative forms of biased estimation to economic matters have not been widely discussed.

In this article, I apply the principal components regression technique to time series rice demand equations for Colombia and Venezuela and enumerate the advantages and disadvantages associated with the technique.

The Problem

Important changes in rice production took place in Colombia and Venezuela after 1956. Rice yields in Colombia increased from a 1956-58 average of 1.8 tons per hectare to 4.1 tons per hectare for 1976-78, while the annual rate of growth in production was 9.1 percent. Rice yields in Venezuela increased only slightly less, from 1.3 tons per hectare to 3.2 tons per hectare for the 1956-78 period, but the increase and improvements in area planted allowed a 15.7-percent annual rate of growth in production for that period, the largest in Latin America (*14*).[1]

The purpose of this exercise was to estimate the impact of the lower real retail prices of rice, the higher levels of income, and the changes in the prices of other closely related foods on the level of per capita rice demand in both countries.

Per capita consumption of rice in any given year, y_i, is defined as apparent disappearance divided by population. Apparent disappearance is defined as production plus imports minus exports, minus changes in stocks.

A doublelog OLS demand specification was selected for per capita rice consumption, y, in both countries.[2] Each equation is of the form:

$$y = XB + u \tag{1}$$

where the independent variables are the logs of the price of rice, the real retail prices of seven other basic foods—corn, wheat flour, potatoes, cassava, plantains, beef, and beans—and per capital real income. I assumed that rice consumption is not related to the prices of other commodities not included in the model.

OLS estimation of the models revealed the following characteristic symptoms of multicollinearity on the parameters of the model; the individual contributions to the R-square value added to less than half its value; most of the *t*-values were low; and some of the elasticities seemed unreasonable (like a

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[1] Italicized numbers in parentheses refer to items in the References at the end of this article.

[2] The period of analysis covers the years 1956-77 for Colombia and 1959-77 for Venezuela; they coincide with the introduction of modern rice varieties in both countries. Italicized characters are nx1 vectors, and X is a 7xn matrix, where n is the number of observations.

positive own-price elasticity and an extremely high income elasticity for rice in Colombia) (table 1). Examination of the simple correlations and of the eigenvalues confirmed the presence of multicollinearity (tables 2 and 3).

Handling Multicollinearity

Perfect multicollinearity exists when a subset of the vectors x_j of the matrix of explanatory variables X are linearly dependent—that is, if there exist nonzero constants, $a_1, a_2, \ldots a_p$, so that: $\Sigma a_j x_j = 0$ (*24*). Perfect multicollinearity is a problem of existence; multicollinearity is a problem of degree (*13*). The practical problem faced by researchers is severe multicollinearity. Because it is a sample problem rather than a population problem, there are no definite tests. Several multicollinearity measures have been suggested (*28*); the most common are the variable correlation matrix and the parameter correlation matrix. Assessing the magnitude of the problem involves subjective judgment. A number of alternative ways for dealing with the associated problems of multicollinearity have been proposed (*16*). A brief description of some of them follows.

- Augmentation of Data. This is frequently mentioned as the best approach. This solution is not practical in our case, as it was not possible to obtain data for a longer period.

- Restricted Least Squares (deterministic or stochastic). This is useful when there is reliable prior information about some of the parameters involved in the multicollinearity problem. This was not the case in this study.

- Variable Deletion. This can ameliorate the degree of multicollinearity. However, the fact that certain of the explanatory variables in a given model appear highly correlated should not be regarded as grounds for changing the specification of the model (*5, 9*). In our case, dropping income from the demand equations would have only worsened the situation by introducing additional errors of specification.

- Transformation of Data. This is useful when the interpretation of the structural hypothesis is not affected by the transformation or is not important to the researcher. Examples of transformations are first differences, ratios of variables, and indexes.

- Ridge Regression. This was first proposed by Hoerl and Kennard. It produces biased estimates, and their expected bias is greatly increased when the parameters are of opposite signs (*2*). This is the case in both equations for the expected own-price elasticity and the income elasticity.

- Factor Regression Analysis. This is based on factor analysis techniques. Principal Components Regression (PC-OLS) belongs to this group. In addition to mitigating the problem of multicollinearity, PC-OLS greatly reduces the influence of outliers in the data. Deleting one or more components to mitigate multicollinearity implies an obvious tradeoff. Unless the true (and unknown) parameter vector lies in the subspace chosen for examination, the resulting estimators will be biased. The tradeoff is between biasedness and reduction in parameter variance.

Single-equation linear models are typically estimated for one of two purposes: (1) to test some theoretical or structural hypothesis, and (2) to use an equation solely as a forecasting tool. In our example, the goal is to estimate the structural relationships between the dependent and the independent variables. With that purpose in mind, we selected PC-OLS to mitigate the problem of multicollinearity.

Principal Components Regression Analysis (PC-OLS)

Principal components are linear combinations of observed variables (the logarithms of the explanatory variables in this case). The components are orthogonal to each other. The first principal component represents the largest amount of variation in the data; the second represents the second largest; and so on (*12*). It is advisable to standardize the variables to avoid scale problems. The PC-OLS model of y on Z is:

$$y = Zd + u \tag{2}$$

Let Z_{nxp} be the matrix of principal components of X. Thus, Z = XC, where C is a pxp matrix composed of characteristic vectors of $X'X$,

From the traditional OLS model, $y = XB + u$, one can find the PC-OLS of y on Z; $y = Zd + u$, where d is a pxl vector of coefficients; and u is the vector of random errors (*3, 6, 7, 8, 9, 11, 15, 17, 18*).

PC-OLS represents a compromise between the criteria of unbiasedness and minimum variance. T. D. Wallace and associates (*26*) have proposed that comparisons between restricted and unrestricted estimators be based on mean square error (MSE). The MSE criterion provides one framework for considering the problem of multicollinearity in a linear model (*29*).

McCallum (*18*) has shown that one can obtain a biased coefficient with a lower mean square error by eliminating some of the components. Because the new biased PC-OLS estima-

Table 1—Doublelog OLS and PC-OLS estimation of per capita white rice demand, Colombia and Venezuela[1]

Country	Estimation method	Intercept	Price of white rice	Price of corn	Price of potatoes	Price of cassava	Price of plantains	Price of wheat flour	Price of beef	Price of beans	Per capita income	$\overline{R}^2$	SER	DW
		B_0	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9			
Colombia	OLS	-1.89 (-1.80)	0.38 (1.49)	0.01 (.09)	-0.32 (-4.30)	0.31 (5.07)	-0.19 (-1.89)	0.25 (2.46)	-0.31 (-2.39)	0.44 (5.38)	2.47 (6.88)	0.97	0.0538	1.73
	PC-OLS[2]	1.71	-.69 (-31.53)	.21 (1.59)	.39 (-4.09)	.38 (5.23)	-0.48 (-12.42)	.10 (1.05)	-.14 (-.99)	.52 (5.46)	.93 (48.86)	.92	.0627	1.54
Venezuela	OLS	1.30 (.53)	-.65 (-1.01)	-.74 (-.82)	.26 (.32)	-.46 (-.53)	1.04 (1.83)	-.42 (-.67)	.05 (.10)	.20 (.40)	.85 (.60)	.71	.1677	1.73
	PC-OLS[3]	1.92	-.59 (-8.32)	.36 (1.68)	.13 (-.56)	-.87 (-3.26)	1.05 (2.00)	-.65 (-2.96)	.08 (2.02)	.03 (.25)	.58 (6.86)	.74	.1546	1.75

[1] Numbers in parentheses are t-values; $\overline{R}^2$ is corrected R^2; SER is Standard Error of the Regression; DW is Durbin-Watson statistic. Critical t-value at 90-percent level is 1.34. All variables are expressed in natural logarithms.
[2] One component is deleted.
[3] Two components are deleted.

Table 2—Eigenvalues and cumulative fractions of variance explained by each component, Colombia and Venezuela

Colombia		Venezuela	
Eigenvalue	Cumulative fraction	Eigenvalue	Cumulative fraction
3.44	0.38	4.83	0.54
1.58	.56	1.84	.74
1.31	.70	1.24	.88
1.02	.82	.44	.93
.68	.89	.26	.96
.38	.95	.19	.98
.33	.97	.11	.99
.22	.99	.06	.99
.02	1.00	.02	1.00

tor has lower variance, it may lie closer to B than the OLS estimator does (*1*). The process of deleting components makes PC-OLS estimates equivalent to linearly restricted OLS estimates (*17*). PC-OLS belongs to the set of Stein-type estimators, as it implies giving up an unbiased estimator in favor of a reduced MSE. Principal components restrictions are known to yield the maximum variance reduction of all sets of linear restrictions of equal size (*7*).

Several tests have been developed to evaluate the bias-variance tradeoff when restricted versus unrestricted OLS estimators are compared. They can be classified into two groups of norms: structural and predictive (*10*).

Theoretically, if one runs a regression equation using all p principal components it will yield the same transformed coefficients as the original regression. The difference can be attributed to the reduction in the roundoff problem because of the decrease of the near singularity in the design matrix.

The transformed coefficients for the normalized data can be obtained from the formula:

$$b_i = \sum_{j=1}^{p} C_{ij} d_j \qquad (3)$$

where b_i is the OLS estimate of B_i, and C_{ij} and d_j are defined as above (*18*). The standard errors of the coefficients are:

$$SE(b_i) = \left[\frac{s^2}{n} \sum_j \frac{C^2_{ij}}{E_j} \right]^{1/2} \qquad (4)$$

Where:

E_j is the eigenvalue of the j_{th} component;
s is the standard error of the regression;
n is the number of observations; and
C_{ij} and b_i are defined as above (*18*).

When a subset of the components is selected, the appropriate C_{ij} and x_j are deleted from the above sum.

Deletion Criteria

We considered two traditional methods in selecting a subset of the components which are used to form PC-OLS estimates: the Characteristic Root Criterion (CRC) and the *t*-value criterion (TVC) (*10*, *19*).

CRC deletes those principal components associated with the smallest characteristic roots of the correlation matrix of the independent variables (eigenvalues). Deletion based on small characteristic roots implies little loss in the variation of the independent variables.

TVC allows the vector *y* of the dependent variables to play a role in the exclusion of the principal components. Components with insignificant *t* values will be dropped. This selec-

Table 3—Correlation matrix of the independent variables, 1956-77[1]

Commodity	Price of white rice	Price of corn	Price of potatoes	Price of cassava	Price of plantains	Price of wheat flour	Price of beef	Price of beans	Per capita income
					Dollars				
Price:									
White rice	1.00	0.01	-0.29	-0.32	0.12	0.49	-0.52	0.22	-0.94
Corn	-.71	1.00	-.08	-.51	.02	.29	-.32	.20	-.02
Potatoes	.34	.21	1.00	.45	.06	-.19	-.01	.06	.23
Cassava	-.72	.68	-.34	1.00	.14	-.38	.51	-.11	.34
Plantains	-.40	.79	.51	.47	1.00	.16	-.03	.45	-.29
Wheat flour	.59	-.71	-.22	-.55	-.67	1.00	-.56	.04	-.60
Beef	-.65	.51	-.29	.44	.11	-.32	1.00	-.15	.61
Beans	.31	.35	.09	-.01	.16	-.47	-.53	1.00	-.24
Per capita income	-.92	.82	-.21	.80	.57	-.66	.54	.16	1.00

[1] Colombia: upper triangular matrix. Venezuela: lower triangular matrix.

Source: Author's calculations.

tion leads to preliminary test principal components (PTPC) (7). Fomby and Hill conclude that "when components are deleted on the basis of statistical tests, the restricted least squares formulation of PC-OLS combined with the preliminary test literature make it clear that any testing procedure may not produce parameter estimates superior in mean square error (MSE) relative to OLS" (*7*, p. 526).

In the cases treated here, the components were not highly correlated with the individual independent variables. An economic interpretation of them was not feasible. Keeping most of the original sample variability in the estimation process was judged as being important. That implies deletion of those components with smaller eigenvalues. In addition, the reduction in variance is inversely related to the eigenvalue. So, it was decided to follow the CRC.

CRC offers an interesting set of possibilities in the bias-precision trade-off. Although the restrictions we consider are sample specific and have no economic interpretation, they may nonetheless yield useful information on the poorly planned experiment (secondary sources) which generated the data. Because those components with the smallest eigenvalues are deleted, the marginal reduction in parameter variance is maximized. This situation occurs because precision is directly related to the size of the eigenvalues associated with the deleted components (*7*).

We imposed a threshold level (95 percent) on the maximum amount of variability of the original data to be kept; that is, after those components with the smallest eigenvalues were deleted, at least 95 percent of the original variability was retained. Suppose that m is the number of components that allow the 95-percent threshold level to be met. The next stage is to estimate a set of PC-OLS equations deleting components one by one, starting with the component with the smallest eigenvalue, until m components are deleted. From that set of equations, we chose the one with the highest corrected R-square. We then tested the resulting mixed estimates against the OLS estimate for generalized MSE superiority (GMSE) based on a noncentral F distribution (*27*) to examine the appropriateness of the restrictions and the various trade-offs between estimator bias and variance reduction, from the structural viewpoint.

Results of PC-OLS Estimation

The 95-percent threshold level imposed for the CRC was met, with up to three and four components deleted in the Colombia and Venezuela equations, respectively (table 2). The corrected R-square was highest when two components were deleted from the Venezuela equation and when one component was deleted from the Colombia equation.

When an appropriate structural test was used, both PC-OLS estimates were found to be superior in the generalized MSE sense (GMSE) to the OLS estimates. To test the hypothesis that a set of constrained estimators, d, is better than the unconstrained estimators, B, according to the GMSE criterion, we used the test and tables developed by Toro-Vizcarrondo and Wallace (*25*). The test is based on the noncentral F distribution of the statistic:

$$a^* = \frac{\text{SSE}(d) - \text{SSE}(B)}{\text{SSE}(B)/(n-k)} \tag{5}$$

where SSE is the sum of squared errors and $n - k$ are the degrees of freedom of the unrestricted equation. The corresponding values were 8.37 and 0.37 for Colombia and Venezuela, respectively, which failed to reject the hypothesis in both cases.[3]

The effects of multicollinearity on the values of the parameters and their variances were more notorious in the rice demand equation for Colombia, particularly on the own-price and income elasticities. The Venezuela PC-OLS equation has a lower standard error of regression than the OLS equation; the gains in parameter precision were important (table 1).

A comparison of the results of PC-OLS and OLS leads to important conclusions about the structural nature of the equations. The PC-OLS Colombia equation exhibits a negative own-price elasticity in contrast to the OLS equation. It also shows a substantially smaller income elasticity. Both elasticity estimates are theoretically more sound, and they are similar to results reported by others (*4*, *21*, *22*). In addition, the two variables greatly reduce parameter variance. These changes are not surprising, as the correlation between them was the highest (−0.94) (table 3). Changes in parameter variance for the cross-price elasticities were relatively small, and there were no sign reversals. Three commodities appear as gross substitutes of rice (corn, cassava, and beans), whereas two are complements (potatoes and plantains) and two are independent (wheat and beef).

The Venezuela equation exhibits a remarkable reduction in parameter variability for all the variables. This is important, as OLS results did not allow any inferences about the individual elasticities (except for the price of plantains) because of insignificant t-values. Where PC-OLS is used, seven of the nine elasticities are significant at the 90-percent level (as opposed to one of nine with OLS estimation). Corn, plantains, and beef are gross substitutes for rice, while cassava and wheat are gross complements, and potatoes and beans are independent (*23*).

[3] The critical value for the Colombia and the Venezuela equations at the 95-percent level are 8.84 and 5.99, respectively (*27*). In both cases, the value of a* is lower than the critical value, which indicates superiority of the restricted, over the unrestricted, estimators in the GMSE sense.

There are some similarities in both PC-OLS equations. The own-price elasticity and the cross-price elasticity of corn are quite similar, and rice is inelastic with respect to income in both countries. However, all the other commodities differ in their relationships with rice in the two countries. This could be due to the fact that the importance of carbohydrate foods in the national diets of Colombia and Venezuela is quite different (*23*).

It is not surprising to find some degree of complementarity among all these staples in the two countries. All are important in their respective diets; it is common to serve two, three, or even four staples at a single meal.

In the predictive sense, the total MSE of prediction for the Venezuela PC-OLS equation was lower than that of the corresponding OLS equation; that was not the case for Colombia. In other words, both PC-OLS equations perform better when a test of structural form is supplied, but only the Venezuela PC-OLS equation does better when the predictive power is tested.

This procedure ensured that multicollinearity was reduced and that the cost (bias) was small and was outweighed by the gains (precision) in the structural sense as indicated by the GMSE criterion. An objective of the estimation process was to quantify the impact of each independent variable on the demand for rice. Therefore, restricting the amount of variability deleted was desirable to increase our confidence in the estimated elasticities. Thus, other PC-OLS equations may be superior in the GMSE sense to the ones selected here, but these equations would have considerably larger biases. Of course, given the complexity of the trade-offs, the decision to select the best deletion criterion in a risk situation is highly subjective.

Mittlehammer and Young conclude that "the researcher plagued by severe multicollinearity is unlikely to find comfort by mechanically appealing to a single estimator whose principal virtue is dominance over OLS in some sense" (*20*, p. 304).

With most of the variability of the data included, the method used here results in more precise estimators which are structurally superior in the GMSE sense to the unbiased OLS estimates. This finding does not imply that the CRC criterion should be used mechanically to delete components. Each problem is unique, and choosing a solution depends on the researcher's goals and preferences as well as on careful analysis of the data and knowledge of the alternatives.

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In Earlier Issues

The opposition to big business practices is frequently not upon the grounds that they are anti-competitive—rather, that the competition is too intense, too aggressive, too ruthless. Economists are revising their ideas about the nature of competition. Our agricultural marketing research has not given enough attention to the problem. What kind of competition do we have in meat packing? In the tobacco industry? In the grocery chain systems? Is this kind of competition good for the farmers and the consumers? If not, what can and should be done about it? What are the extent and kinds of Government regulation that are needed?

Frederick V. Waugh
Vol. 7, No. 2, April 1955, p. 54

Alternative Indicators of Farm Operators' Earnings

By Roger P. Strickland*

Abstract

Official U.S. Department of Agriculture (USDA) estimates of net farm income, measured in nominal dollars, have fluctuated widely over the past few years. When measured in real dollars, net farm income has trended downward; in the aggregate, it approaches the levels of the thirties. Far fewer farm operators share in the aggregate; resource efficiency is far greater now than in the thirties; and agriculture's financial management has become increasingly complex and sophisticated. Therefore, USDA measures of net farm income may not be reliable indicators of farm earnings. This article analyzes several alternative indicators of operator earnings.

Keywords

Net farm income, farmland appreciation, agricultural tax preferences

The statistic most widely used as an indicator of the earnings of U.S. farm operators is the U.S. Department of Agriculture's (USDA's) estimate of net farm income. Some limitations of this statistical aggregation across a wide range of farm types, farm sizes, and commodities are generally acknowledged. Other deficiencies may not be so apparent.

Chronic inflation in the U.S. economy has affected relative prices and has altered the priorities of farm operators. To operators, the value of the production of agricultural commodities has decreased relative to other economic activities that are peripheral to production.

One such activity is investment in farmland. In less inflationary times, decisions regarding the purchase of farmland were probably based principally on its value in production and on reducing uncertainty. Chronic inflation, in combination with substantial liberalization of the terms under which land purchases could be financed, have changed the profitability and relative importance, to farm operators, of investing in farmland (table 1). Prospective earnings from highly leveraged purchases of appreciating land were sufficiently attractive to warrant diversion of a farm operator's attention away from commodity production.

Tax planning is a second economic activity peripheral to commodity production; its effects on the operator's finances have increased under inflation. The progressive nature of the income tax is a major reason for this relationship. A contributing factor is the tendency for the Congress to reduce the average rate of taxation by legislating various means of sheltering income through deductions and exclusions. Whereas lowering of marginal rates of taxation would automatically reduce taxes, increased sheltering of income puts the burden of implementation on the farm operator.

*The author is an agricultural economist with the National Economics Division, ERS. He wishes to thank Allen Smith and two anonymous reviewers who made suggestions which improved the analysis here.

Table 1—Operators' net farm income, nominal and real, 1930-81

Year	GNP implicit price deflator[1]	Operators' net farm income	
		Nominal[2]	Deflated[3] dollars
	1972=100	*—Million dollars—*	
1930-34 average	27.7	3,023	10,898
1970	91.5	14,151	15,474
1971	96.0	14,633	15,241
1972	100.0	18,665	18,665
1973	105.7	33,349	31,551
1974	114.9	26,130	22,738
1975	125.6	24,475	19,493
1976	132.1	18,682	14,141
1977[4]	139.8	18,391	13,152
1978	150.1	26,458	17,633
1979	162.8	32,697	20,088
1980	177.4	19,860	11,195
1981	193.6	23,000	11,880

[1] *Economic Report of the President Transmitted to the Congress*, Feb. 1982, table B-3.
[2] Data through 1980 are from (*15*, tables 80-82). The 1981 estimate is from (*14*, p. 9).
[3] Computed by dividing the first column by 100 to convert to a simple ratio and by dividing the results into the second column.
[4] Based on the 1974 Census of Agriculture definition of a farm, which is sales of $1,000 or more; this definition applies to 1977 and all subsequent years.

An operator who gives no thought to income taxes except for completing the tax forms typically pays more taxes than one who allocates time to tax planning. Therefore, as with investing in farmland, tax planning is an economic activity separate and distinct from commodity production.

A farm operator is a producer of agricultural commodities, a land investor, and a tax planner. Many decisions represent compromises to achieve a balance among two or more objectives—for example, purchasing land rather than renting, timing of purchases and sales, and formulating strategies for replacing equipment.

To get an indication of the level and changes in an operator's financial status, one can measure the costs and returns to each activity separately and then aggregate the net benefits or earnings across activities, or one can measure the aggregate costs and the aggregate benefits and then take the difference. This procedure is not an academic exercise because consistent determination of appropriate costs and benefits cannot be made prior to a decision regarding the economic activities that those results are to measure.

Net Farm Income

The USDA net farm income statistic is correlated to, but not entirely comparable to, what an operator reports to the Internal Revenue Service (IRS). The principal difference is in the treatment of depreciation. The IRS uses a cost basis and permits rapid depreciation unrelated to an asset's useful life. USDA uses replacement value as the basis for depreciation, which yields a higher annual depreciation than the cost basis, and USDA relates that depreciation to the asset's useful life, which yields a lower annual depreciation.

USDA's net farm income series deducts production expenses from gross farm income. Gross farm income is composed of the following: (1) receipts from sale of farm commodities, (2) value of inventory change, (3) direct Government payments, (4) other farm income (custom work, recreational income, and so forth), and (5) value of home consumption.

Total production expenses are composed of the following: (1) fertilizer, chemicals, and seeds; (2) fuel, repair, and operations of machinery and equipment; (3) hired labor; (4) machine hire; (5) depreciation; (6) interest, including real estate; (7) property taxes; (8) net rent to nonoperator landlords; and (9) purchase of farm commodities, such as feed and seed.

Two possible reactions by agricultural producers to high marginal tax rates are to illegally conceal income or to legally shelter income from the IRS. Assuming the latter strategy, the potential impact on USDA's net farm income estimates that result from tax planning should be evaluated; consideration should then be given to possible changes in the components in net farm income. Perhaps a farm income series after taxes should also be investigated.

Agriculture's Tax Preference

Two readily available methods of effectively sheltering income are tax deductions for interest and depreciation. Farm real estate interest and taxes are particularly attractive as income tax shelters. In situations where a farmer has been able to finance a purchase with a long-term mortgage requiring only a small downpayment, most of the costs associated with landownership for the first 10 years are interest and taxes. The Government would contribute a share of the cost.

Davenport, Boehlje, and Martin have analyzed some of the pressures placed on the structure of American agriculture by the effects of tax policies and note that in a tax-favored industry, such as agriculture with its use of cash accounting, the annual returns on investment consist of the commerical returns from the sales of commodities produced and the return from the management of tax assets and liabilities (*1*).[1]

The authors conclude that tax policy has exerted upward pressure on the price of farmland and that this fosters a substitution of capital for labor and causes farm operators to alter management practices in order to take advantage of tax preferences. They also contend that the tax system not only enhances the earnings of farm investors and operators, but that the benefits of the tax advantages are frequently more certain than the return from production. A greater degree of certainty, of course, translates directly into an enhanced value being placed on these benefits, relative to those having a higher degree of risk.

Investing in farmland and legally avoiding payment of taxes is smart financial management. The problem is that the gains from appreciation of the land and the taxes avoided are not reflected in USDA's net farm income estimates, but the cost of additional interest on the farm's real estate mortage and additional property taxes are included. Hence, USDA's estimates are biased toward a lower income than that perceived by farmers.

The situation regarding the use of depreciation to reduce taxes is similar. By using additional first-year depreciation and accelerated depreciation procedures, farmers can write off a substantial portion of their purchases in the first year and most within the first 2 or 3 years. With the Government paying perhaps half the costs through deductions and credits, management of equipment purchases becomes as much an element of financial planning and cash flow strategy as it is an element of agricultural production.

The cost of trading up to larger equipment or to the newest technology or of buying ahead for expansion would show up in USDA's farm income accounting on the expense side as

[1] Italicized numbers in parentheses refer to items in the References at the end of this article.

increased depreciation, interest charges, and property taxes. But, the benefits accruing to the tax management activity would not be directly reflected, even though they might be partially and indirectly reflected in subsequent years through higher productivity, lower capital expenditures, and future earnings on current taxes not paid.

Tax management is a legitimate and profitable activity that generates definite financial gains from taxes not paid. Implementation generates additional income and expenses. USDA's net farm income series may include many of the additional expenses, but few of the benefits. The result is an underestimation of farm income.

USDA could improve accuracy by redefining farm income. One alternative is to correct the weaknesses and omissions of the current series which reflect three related activities—commodity production, real estate investing, and tax planning. Another alternative is to separate the income and expenses associated with two or more of the activities. The choice is a function not only of the types of information desired and the analysis to be performed but also of the costs of implementing each alternative, particularly the cost of obtaining data not currently available.

Farmland Appreciation

There are two alternatives for handling farm real estate. The ownership of real estate can be treated as an investment unrelated to production. Ownership is not a prerequisite for farming, nor is it a factor of production. Land is the factor of production, and the right to use it may be acquired by leasing.

Treating real estate as an investment is consistent with the way the Department of Commerce handles residential dwellings in its Personal Consumption Expenditures component of its Gross National Product accounts, where ownership of dwellings is treated as a investment and a rental charge is included as an expenditure (*17*). This approach is also consistent with the recently announced changes for housing costs in the Consumer Price Index.

A separation of the costs and returns attributable to real estate investment from USDA's current farm income series requires two changes in the current procedure. One is the addition of the two real estate ownership costs—interest and taxes—which are now deducted as production expenses. The second is to deduct, as a production expense, the opportunity cost of operator-owned real estate by use of an imputed rental value.

A second alternative for handling farm real estate is to leave in the expense items and include an estimate of the benefits, positive or negative, accruing from change in value of farm real estate.[2] A major difficulty in implementing this alternative is allocating the change between operator and nonoperator landlords. USDA's income series measures the earnings of farm operators; therefore, only the appreciation in value of farmland owned by operator landlords could be included. This allocation is not made in USDA estimates of change in the value of farm real estate.

The tax-sheltering component of the benefits and costs related to depreciable equipment is less clear and even more difficult to isolate. It is not likely that farmers would purchase equipment simply because the Government would reimburse them for up to half the purchase price, but it would certainly increase the attractiveness of potential acquisitions.

The effects of making tax management a key objective of farm management would be: (1) replacement of machinery sooner than operators would otherwise to gain reliability during critical operations, (2) an increase in mechanization, and (3) the purchase of excess capacity to allow for expansion. The tax-sheltering benefits could be viewed as a self-perpetuating source of funds for continuous expansion. With multiyear loans, the savings in the early years could exceed loan payments.

Estimates for 1975-80 show the empirical significance of the possible underestimation of net farm income due to tax management and appreciation. The actual underestimation depends on one's assumptions regarding what definitional changes should be made to the current farm income series. What follows is intended as illustrative, rather than as definitive. Table 2 contains data for adjusting the published series, and table 3 presents the adjustments.

Currently, USDA includes interest and taxes on farm real estate in farm production expenses. The aggregate value of all farm real estate for each of the 50 States and the United States as of February 1 is published annually. The February 1 to February 1 difference in real estate value can be used as a reasonable approximation of the change occurring during the calendar year.[3]

Making a reasonably accurate apportionment between operator and nonoperator landlords for the change in value of real estate is extremely important, given the large values involved relative to the size of the other factors. The ratio in table 2 used to make this allocation was taken from an extensive survey of U.S. landownership (*6*). Annual information on the occupation of recent land buyers agrees with this ratio (*16*, table 21).

[2] Melichar has explained why capital gains are necessarily a significant portion of the total return to farm real estate (*2*, *7*, *8*).

[3] Alternative conceptual approaches for valuing unrealized farm land capital gains as income have been proposed (*4*, *5*, *9*, *10*, *11*), and the reader might want to consider them before using a simple difference in future analyses.

Table 2—Earnings and expense items included or excluded from farm income under alternative definitions

Year	Interest on real estate[1]	Taxes on real estate[2]	Rent to operator-owned real estate[3]	Income equal to one-fourth of depreciation[4]	Change in real estate value[5]
	Billion dollars				
1975	3.4	2.9	5.9	3.1	[6] 35.7
1976	3.9	3.1	5.4	3.4	44.1
1977	4.4	3.3	5.2	3.7	32.8
1978	5.1	3.0	6.3	4.2	56.4
1979	6.2	3.2	7.0	4.8	56.7
1980	7.3	3.5	7.5	5.3	40.7

[1] Interest on "real estate debt including operator dwellings" published in (*15*, table 61).
[2] Unpublished component of "business taxes" published in (*15*, table 2).
[3] A net rent imputed to farm real estate owned by operators as follows:
(a) Deduct net-rent-paid-to-operator-landlords from the expense item net-rent-paid-to-all-landlords to get net rent paid to nonoperator landlords (*15*, table 2).
(b) The ratio of percentage of operator-owned farmland (56.4) to percentage owned by nonoperator landlords (43.6) times the net rent to the latter group equals imputed rent to former group (*15*, table 1).
[4] Twenty-five percent of the depreciation reported in (*15*, table 64).
[5] Change in the total value of farm real estate (*16*, table 6) multiplied by the share of operator-owned farmland (56.4 percent) (*6*).
[6] Real estate value reported on March 1 in 1975 and on February 1 for later years. The 1975 value was converted to a February 1 basis.

Table 3—Operators' realized net farm income, real estate investment income, and tax savings from depreciation activity, 1975-80[1]

Year	Published USDA estimate	Real estate as separate investment activity[2]: Before adjustment for depreciation	Real estate as separate investment activity[2]: After adjustment for depreciation
	Billion dollars		
Current dollars:			
1975	24.5	24.9	28.0
1976	18.6	20.2	23.6
1977	18.4	20.9	24.6
1978	26.5	28.3	32.5
1979	32.7	35.1	39.9
1980	19.9	23.2	28.5
Deflated dollars, 1972=100:			
1975	19.5	19.8	22.3
1976	14.1	15.3	17.9
1977	13.2	15.0	17.6
1978	17.7	18.9	21.7
1979	20.1	21.6	24.5
1980	11.2	13.1	16.1

[1] Estimates in columns 2 and 3 computed from column 1 and data from table 2. I computed the deflated value by dividing the current-dollar estimates by the price index from table 1.
[2] Includes taxes and interest on real estate from production expenses and excludes rent to operator-owned real estate.

Tax Benefits of Depreciation

To allocate depreciation expenses between tax planning and farm production, I considered 25 percent of the depreciation expense as income resulting from taxes avoided in response to tax shelter incentives. My rationale is as follows: Assume that equipment purchases permit a tax reduction of roughly half the purchase price. Large, commercial farmers purchase most of the equipment, particularly when measured in purchase value, and they concentrate their purchases in high income years. Assuming a marginal tax bracket of 50 percent, the combination of the depreciation and tax credits for purchases should permit farmers to avoid taxes equal to at least half their purchase price. For tax purposes, machinery and equipment are typically depreciated over a period that is no more than half, and often much less than half, their useful life. Accelerated depreciation procedures in combination with short writeoff periods allow savings to be concentrated in the first half of the truncated writeoff period. On the premise that the tax savings are, at a minimum, captured twice as fast as under a depreciation procedure approximating the actual rate of consumption, and assuming the 50-percent tax rate, then $0.5 \times 0.5 = 0.25$ is the portion of the depreciation charge considered as income accruing to these tax-avoidance activities.

Implications for Farm Income

The extent of underestimation (if any) of farm income resulting from a downward bias in the procedure due to the effects of chronic inflation and the structure of the income tax code is likely to increase as the trend in the tax policies on depreciation moves towards expensing or fully depreciating the asset in the year purchased. This trend will greatly increase the ability of operators to adjust in the short run and to smooth out the high-income years with large purchases of additional, depreciable equipment. As in the past decade, the full deductibility of interest and real estate taxes also allows farmers to flatten out the long-term rate of ascension in farm income. Whenever operators conclude that a sustainable increase in actual farm income has occurred, they can intensify their efforts to purchase land, bidding up the price of land and letting the Government make a significant portion of the payment through taxes foregone. At worst, farmers assume they will have to sell the land for a profit if their cash flow turns negative.

A high marginal tax rate makes the purchase of additional land very attractive and likely accounts for much of the seemingly unrelenting pressure for farmland purchases as an investment. The progressive tax structure is regressive in its assistance to land purchasers. In the early years after purchase, when payments are almost all interest and taxes, the farmer in the 50-percent marginal tax bracket gets half the payment back, but the farmer in the 20-percent marginal tax bracket gets back only a fifth. A buyer with no taxable income gets no tax refund and, thus, no Government assistance.

The Congress does reduce the effective average or *de facto* marginal tax rates from time to time, but it does so indirectly by increasing deductions and credits to allow sheltering of reported income. The absolute level of the top marginal tax rate is highly symbolic and politically sensitive (that is, the rich should pay their share) and is thus difficult to lower. The U.S. tax code has become more complex and indirect, but USDA's definition of farm income has not changed accordingly.

The proposed adjustments to the current definition of operators' net farm income do significantly raise the estimates (table 3). Both sets of adjusted estimates reflect the exclusion of costs resulting from investment in farm real estate. A rental charge for operator-owned land is included as a cost of production.

Table 2 shows the change in real estate value. The appreciation in value of real estate is not totally unrealized earnings prior to being sold; the owner may benefit or lose monetarily from the change in value without selling. The equity can be realized through borrowing. The change in current market value affects the borrowing power of the owner. Unmortgaged equity may be treated as a form of savings for emergencies and retirement. There can be a direct tradeoff within an individual's portfolio between equity in real estate and other assets—for example, stocks, bonds, certificates of deposits, and cash. As the real estate changes in value, it may be offset by changes in other instruments in the portfolio. For example, after substantial appreciation in the value of real estate, other assets might be sold and future planned savings reduced or discontinued. Both actions, taken in response to increased real estate equity, provide additional money for consumption, savings, and investment that would not otherwise be available.[4]

Conversely, real estate is usually considered a balance sheet item, and the desire for accounting consistency could dictate separating the costs and benefits of real estate investment from production income. There are two reasons for not doing so. One is a relative lack of confidence in the result because adequate data are not available. The other is that commodity production as an income-producing activity has diminished in importance relative to real estate investing to the point that for many landowning operators, it may not be worth the added expense of separating the earnings from the two financial activities.

One alternative for quantifying the current income effect is to make assumptions regarding the future sale date of the property, the applicable taxes, and the appropriate discount rate, and then to discount the after-tax change in value back to the current period. Another alternative is to attempt to derive the current income effect of the change in value as if realized through loans obtained by use of the change in value within the year as loan collateral.

This latter effect would certainly be much less than the change in value estimated in table 2 for several reasons. First, lenders will not make loans equal to 100 percent of the appraised value. Second, changes in appraised value tend to lag or be more conservative than changes in market value as appraisers await evidence that these changes are not temporary. Third, the interest and any other costs of the loan have to be deducted.

One can sense the importance of making adjustment for appreciation of real estate value by comparing the change in real estate value (table 2) with the reported USDA estimates of net farm income (table 3).

The benefits accruing from taxes avoided when operators avail themselves of depreciation and tax credit incentives are small relative to changes in real estate value, but these benefits are likely to be a substantial percentage of net income from production of agricultural commodities. All the associated costs—additional depreciation, taxes, and interest; professional tax consultations; and labor hired to allow operators to do tax planning—are already included in the current accounting for net farm income, but none of the benefits from taxes saved is included. It would be difficult to separate out the costs. Although allocation of benefits to that activity might be somewhat arbitrary, it deserves serious consideration.

Conclusion

The income tax codes have evolved over time by allowing the sheltering of income rather than by reducing the marginal tax rate. Appreciation in land values is highly correlated with the rate of inflation, and the value of earnings from appreciation is enhanced considerably relative to earnings from producing commodities because appreciation is taxed at the capital gains rate (*13*).

[4] John Rutledge, president of Claremont Economic Institute, presents a lucid discussion of the concept of portfolio balance and the resulting strategies in time of high rates of inflation in (*12*).

Thus, farming has become a highly integrated package of three activities: (1) production of agricultural commodities, (2) tax planning, and (3) real estate investment. To adequately derive the revenues and expenses associated with each activity, one needs a detailed knowledge of the interrelationships to separate the farm establishments' expenses and revenues by the accruing activity. Sufficient data are probably not available to support either an empirical determination of the methodologies required for a separate series or an accurate estimate of the resulting income statistics. Commissioning a scholarly analysis of the methodologies and data requirements would require substantial additional resources; this is unlikely, given the current economic situation. Nonetheless, improved measures of the three activities combined are economically feasible.

Perhaps the more useful approach is to increase the use of alternative financial statistics which are either already available or which can be determined from available statistics. Having several indicators in addition to net farm income may permit a more effective analysis. At any given time, multiple indicators may provide additional information, confirm or disprove a specific issue, and suggest other hypotheses. Two such indicators would be cash flow and farm income after taxes.

Cash flow is important because it indicates the money a firm has available for paying expenses and debts and for making new investments. Cash flow includes depreciation allowances; thus, it reflects changes in the tax laws that allow the exclusion of income through depreciation.

An estimate of farm income after taxes would incorporate the costs and benefits of tax planning. An after-tax income series would, of course, show a different level of income than the current before-tax series, but more important, it would show a different year-to-year change and a different trend over the last decade. The difference in trend could well lead to different conclusions about changes in the financial condition of agricultural producers than would analyses based on current USDA series.

A separate estimate of the changes in value of farm real estate might be computed and combined with the other indicators. As both the question of the appropriateness of including the change in the value of farm real estate and the choice of methodology for valuing that change would likely be extremely controversial, users could exclude the estimate or add it to another indicator as they saw fit.

Doll and Widdows found that using the traditional valuation model, V = R/d, leads to the conclusion that funds invested in agriculture earn their opportunity cost only if real capital gains are added to annual asset earnings. They believe that this interpretation depends upon the acceptance of the equivalence of the real capital gains and the annual income flow (*3*).

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Research Review

Cross-Sectional Analysis of Wheat Import Demand among Middle-Income Developing Countries

By Cathy L. Jabara*

Agricultural economists have been much interested in measuring the export demand elasticity for U.S. agricultural products (*2, 4, 7, 10*).[1] It is difficult to identify this parameter precisely because of its sensitivity to the import demand elasticities of other countries—the parameters of which are often unreliable. In the case of wheat, a knowledge of the import demand elasticities for developing countries is especially important because these countries represent over 60 percent of the U.S. market for commercial wheat sales. The developing-country market share of wheat, however, is characterized by many importers, each holding a relatively small share of U.S. exports. Researchers often find it difficult to obtain reliable time-series data from which they can estimate models of import demand for individual developing countries.

In this article, I utilize pooled cross-sectional and time-series data to estimate a reduced-form import demand model for wheat for 19 middle-income developing countries for the 1976-79 period. These 19 countries accounted for about 40 percent of U.S. wheat exports in 1980. Elasticities estimated from this model are shortrun, and they represent averages for the countries in the sample. Provided there are no structural differences among countries, such estimates may be more reliable than those estimated for individual developing countries from time-series data because the number of time-series observations necessary for parameter estimation is reduced. By extracting information about the regression parameters from the between-country and between time-period variation, the pooling procedure increases the amount of useful information that can be drawn from the available data.

Model Specification

Specification of import demand functions is discussed extensively by Leamer and Stern (*8*) and by Abbott (*1*). Following Abbott, Hall (*5*), and Gallagher and others (*4*), I estimated the reduced-form import demand equation as follows:

$$WM_{it} = A + B_1 \, POP_{it} + B_2 IMC_{it} + B_3 WST_{it-1} + B_4 P_{mit} + B_5 WP_{it} + B_6 PRODW_{it} + B_7 FAID_{it} + \epsilon_{it} \quad (1)$$

for i = 1 ... n countries and t = 1 ... 4 years.

The variables used in the model are:

WM_i = total concessional and commercial wheat imports by country *i*, 1,000 metric tons;

POP_i = population in country *i*, millions of persons;

IMC_i = real foreign exchange availability in country *i*, millions of 1975 U.S. dollars;

WST_i = carrying wheat stocks in country *i*, 1,000 metric tons;

P_{mi} = consumer price of wheat in country *i* (resale price to mills or wheat-equivalent price of bread or wheat in flour), deflated by the consumer price index in country *i*, in 1975 U.S. dollars per metric ton;

WP_i = world price of wheat in country *i*, deflated by the consumer price index in country *i*, 1975 U.S. dollars per metric ton;

$PRODW_i$ = production of wheat in country *i*, 1,000 metric tons;

$FAID_i$ = concessional wheat shipments to country *i*, 1,000 metric tons; and

ϵ_i = a random error term.

Data are for 19 countries from 1976 to 1979.[2]

All countries in the sample except Venezuela and El Salvador controlled the level of the consumer wheat price during the estimation period. I estimated equations using the internal price of wheat, P_m, and the world price of wheat, WP, as an alternate measure to determine the extent to which world prices affect decisions by governments and private firms to import wheat despite internal price control.

Empirical Results

Pooling of time-series and cross-sectional data assumes that structural coefficients are the same across countries. How-

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[1] Italicized numbers in parentheses refer to items in the References at the end of this article.

[2] Equations were also estimated by use of per capita income as an alternative measure of import purchasing power and by use of nominal (undeflated) prices (see *6*).

ever, there may be differences in the country-specific intercepts over time because of socioeconomic and culutral differences. For unpooled statistical procedures, these effects are normally captured in the error term or in the coefficients of the variables which are not country-specific. Uncorrected variation of the error term may cause both bias and inefficiency in an ordinary-least-squares (OLS) estimation of the structural coefficients.

To account for differences in intercepts, I estimated import demand equations using a variance components method in which the intercept terms are treated as random variables—one a time-series variable and the other a cross-sectional variable (*9*, pp. 326-29). This procedure extracts information on the regression parameters from the between-country and time-period variation in the data, in contrast to the ordinary-least-squares with dummy variables procedure (LSDV) which treats cross-sectional and time-series effects as fixed parameters. I assumed that the mean effect of the random time-series and cross-sectional variables is included in the intercept terms and the random deviations about the mean are included as components of the error term. I used a weighted-least-squares estimation technique in which observations were weighted in inverse relationship to their variances. Provided the intercept terms vary randomly, the corresponding generalized-least-squares (GLS) estimates are more efficient than those estimated from OLS or LSDV procedures.

Results indicated significant differences in response to economic variables among countries classified as wheat-producing and nonwheat-producing. Therefore, regression results for these two groups are shown separately. Nonwheat-producing countries are those in which wheat production is zero or minimal. Nine nonwheat-producing countries include Colombia, the Dominican Republic, Ecuador, El Salvador, Indonesia, the Republic of Korea, the Philippines, Taiwan, and Venezuela. Ten wheat-producing countries include Algeria, Brazil, Chile, Egypt, Iraq, Mexico, Morocco, Peru, the Sudan, and Tunisia. A description of these countries and the data used in the analysis can be found in (*6*).

Results also indicated significant differences in the parameter estimates when the Republic of Korea and Egypt are excluded from their respective samples.[3] Table 1 presents equations including and excluding these countries. These differences are largely attributable to the importance of food aid to these countries during the estimation period.

The equations appear to fit the data well; most of the estimated parameters are significant at the 10-percent level or higher. Wheat imports of nonwheat-producing countries appear to respond to world price signals despite internal government control, and estimated responses to world and internal wheat prices are not significantly different. The significance of the world price declines with the inclusion of the Republic of Korea, which suggests that the wheat price stabilization fund operated in that country permits a lag in response to world price levels compared with the other countries. Wheat imports of wheat-producing countries do not appear to respond to world price signals. This implies that wheat import demand elasticities are close to zero for these countries, and it indicates a greater concern for importing target quantities of wheat regardless of price.

Elasticities

Elasticities shown in table 2 indicate that the response of wheat imports by middle-income developing countries to world price, foreign exchange, and quantity changes is quite low. Calculated price elasticities are shortrun; that is, they represent the response to world wheat price changes at fixed production. The finding that wheat imports by nonwheat-producing countries respond to world price signals is in contrast to the results of Abbott (*1*) who found, using time-series data from 1951 to 1973, only three developing countries—Egypt, Mexico, and Thailand—responsive to world wheat price movements.

Low response to world price movements by middle-income developing countries suggests that the shortrun export demand elasticity for U.S. wheat is also quite low. Bredhal, Meyers, and Collins (*2*) estimated the foreign demand elasticity for U.S. wheat was between 0 and −1.67, depending on the assumptions made about the degree of price insulation among developing countries. Gallagher and others (*4*) estimated the export demand elasticity for U.S. wheat to be −0.41. They assumed that foreign demand elasticities for wheat in Western Europe, in Japan, and in the Soviet Union and other centrally planned countries are zero, so that their domestic elasticity depended on the aggregate import demand elasticity estimated for the developing countries (−0.71).

These results indicate that developing countries which import about 20 percent of U.S. wheat respond to world price signals, but the response is low—about −0.2. Wheat-producing countries, which also import about 20 percent of U.S. wheat, do not appear to respond to world price movements. Final determination of the elasticity of export demand for U.S. wheat depends on the estimated response of other developing countries which accounts for the remaining 20 percent of U.S. sales.

[3] I conducted a series of preliminary F-tests using results from LSDV estimation to test for structural differences among countries within the two samples. This procedure tested whether the observations for each country came from the same population as the observations for the other countries in the sample (*3*). The addition of observations for the Republic of Korea and Egypt significantly changed the parameters of the estimated equations. These tests used the LSDV procedure because tests of equality of slope coefficients are rarely done using the variance-components framework, and the results are valid only if the samples are sufficiently large (*9*, p. 329).

Table 1—Wheat import demand equations, variance components estimates

Samples and variables	Regression coefficients (with t-ratios)									
	A	POP	IMC	WST_{t-1}	P_m	WP[1]	PRODW	FAID	RMSE[2]	PRMSE[2]
Nonwheat-producing countries:										
Eight-country sample[3]										
Real internal price	287.4 (2.72)	6.327 (3.46)	0.0296 (3.43)	−0.6217 (−2.07)	−0.5391 (−2.03)		−1.015 (−.66)	0.1095 (.52)	37.14	0.068
Real world price	283.8 (2.76)	6.386 (3.51)	.0328 (3.71)	−.6478 (−2.15)		−0.7333 (−2.13)	−1.000 (−.66)	.0893 (.43)	36.91	.067
Nine-country sample[4]										
Real internal price	392.6 (2.40)	6.020 (2.11)	.0301 (2.61)	−.9498 (−2.48)	−.7790 (−2.13)		2.941 (1.79)	.5884 (3.01)	54.27	.079
Real world pricc	377.3 (2.38)	6.082 (2.13)	.0341 (2.92)	−.9893 (−2.51)		−.9893 (−2.00)	3.184 (1.87)	.6074 (3.05)	55.60	.080
Wheat-producing countries:										
Nine-country sample[5]	829.1 (1.88)	33.88 (4.33)	.0641 (4.17)	−.6398 (−1.97)		−1.373 (−.89)	−.5707 (−4.80)	.1292 (.08)	154.36	.122
Ten-country sample[6]	653.31 (1.63)	29.94 (3.88)	.0710 (3.57)	−.4357 (−1.14)		−1.046 (−.63)	−.4803 (−3.26)	2.466 (5.95)	202.38	.128

Blanks indicate not applicable.
1 World wheat price.
2 RMSE denotes root mean square error, and PRMSE is RMSE divided by the mean of the dependent variable.
3 Colombia, the Dominican Republic, Ecuador, El Salvador, Indonesia, the Philippines, Taiwan, and Venezuela.
4 Eight-country sample and the Republic of Korea.
5 Algeria, Brazil, Chile, Iraq, Mexico, Morocco, Peru, the Sudan, and Tunisia.
6 Nine-country sample and Egypt.

Table 2—Wheat import demand elasticities computed at means, middle-income developing countries

Variables	Country equations			
	Nonwheat-producers (with Republic of Korea)		*Wheat-producers (with Egypt)*	
POP	0.38*	(0.29)*	0.84*	(0.60)*
IMC	.37*	(.34)*	.32*	(.25)*
WST_{t-1}	-.10*	(-.14)*	-.15*	(-.10)*
WP	-.18*	(-.18)*	-.11	(-.07)
PRODW	-.02	(.07)*	-.57*	(-.40)*
FAID	.01	(.06)*	.01	(.30)*

*Significant at the 10-percent level or greater.

Conclusions

Pooling may not greatly advance import demand estimation; however, it may be particularly helpful and cost-efficient when there is little information about a group of small importers, such as the developing countries. More important, reliable time-series data often do not exist for developing countries so that parameter estimates from pooled data may be more reliable than estimates from single-country estimation, provided structural differences do not exist among countries.

It is not strictly valid to aggregate developing countries in modeling research. Wheat import demand behavior among middle-income countries differs by the internal policies of governments and by the importance of wheat in the economy. The finding of differences in price-response behavior between nonwheat-producing and wheat-producing countries should be tested further with analysis of wheat import demand in low-income countries.

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In Earlier Issues

The services of many workers are required to get products from farmers to consumers in the form, time, and place desired. . . . During the last quarter of a century workers in food marketing firms increased about 50 percent whereas workers on farms decreased about a third. . . . The increase in physical output marketed per man-hour was equivalent to an annual average increase of around 2 percent.

Kenneth E. Ogren and Kathryn Parr
Vol. 7, No. 2, April 1955, pp. 42, 46-47

Some Lessons from Wingspread: A Report on the National Rural Symposium

By J. Norman Reid*

Rural governments are at a critical juncture. Many are faced with large population inflows that differ from any in their experience. At the same time, the Federal, State, and local government system may well be on the verge of a significant restructuring. These changes pose important challenges for local governments in meeting their responsibilities; they also present new opportunities for rural communities to shape their futures. Prospects of success for rural communities will depend on the performance of their local governments.

These were the dominant themes of the National Rural Symposium, which was organized around the topic, "Rural Governments in a Time of Change: Challenges and Opportunities." Held March 29-31, 1982, at the Wingspread Conference Center, Racine, Wis., the symposium brought local government officials together with State, Federal, and university representatives to consider major social and political changes and their implications for the future of rural America. The symposium was jointly sponsored by the U.S. Department of Agriculture (USDA) and the Rural Governments Coalition, whose members include national organizations representing the Nation's counties, towns and townships, development districts, and regional councils. The session was organized around four papers that outlined the governmental and demographic changes affecting rural communities and their governments and that considered implications for local service delivery and resource availability.[1]

The sweeping changes now confronting the Nation's governmental system affect all levels. Participants were not able to predict the full effects of the New Federalism on rural governments, but they were clear about several points.

They voiced little concern about the loss of Federal dollars, even though the recent cuts climax a decade of increased rural access to these funds and follow several years of decline in real revenue levels. Much greater attention centered on federally mandated service standards—especially related to drinking water and wastewater treatment—which continue to be a sore point with many localities. Concern also focused on emerging State government roles and whether local governments—still heavily regulated by States—will get added discretion to match their new responsibilities.

The symposium focused on the "rural renaissance" of new population growth and economic activity—without precedent in this century—that much of rural America is experiencing. For newly growing places that had become accustomed to a slow but steady loss of residents, this turnaround presents the challenge of planning and financing new, needed services and coping with disruptions to their social structure. Still, many rural places continue to lose residents and, for these, the challenge is finding acceptable ways to cut some services while enhancing others.

Participants addressed several issues related to service delivery: the costs and effects of providing local services, relationships among governments and with the private sector, and local institutional capacity. In addition, they considered three areas related to governmental resources: human, organizational, and financial. From these a number of rural development research and information needs emerged. Some of the leading issues are considered below.

Among the most widely cited needs were training and information for local policymakers and for the rural public at large. Citizen-officials predominate in small governments, and lack of prior government service is common. This situation creates special training needs for rural governments that differ from the needs of large governments. In addition to training in technical skills, these officials often need general orientation to the job of governing. But, even more important than more training may be finding ways for officials to take advantage of it. And, how the training is delivered can be as significant as its content.

Researchers have an important role in addressing these needs. Social and psychological factors have important effects on whether training programs reach their target audiences and, when they do, on whether they are effective. Understanding these factors and finding ways to address them can help improve the effectiveness of training programs.

The most apparent needs are for training in specific skills, such as financial management or capital budgeting, and for information that can be applied to particular problems—revenue forecasting, for instance. Less recognized, and perhaps more needed, is guidance about issues like the productivity of alternate revenue sources and their probable effects on equity or economic growth. But, in these and other areas,

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[1] The papers were "Rural Governments in the Eighties: Adapting to Change," by William E. Bivens, III; "Demographic Changes in Rural America: Shaping Rural Governments," by Peter A. Morrison and Kevin F. McCarthy; "Government Service Delivery: Meeting Community Needs," by Robert Paciocco; and "Resources for Rural Governments: Finding and Using Community Assets," by Alvin D. Sokolow. Copies of the papers may be obtained from the author at USDA/ERS/EDD, Room 494-GHI, 500 12th Street, S.W., Washington, D.C. 20250. A final report and proceedings are planned.

new directed research may be required to fill specific knowledge gaps. In all areas, basic knowledge needs to be converted into forms that can be shared with community officials and the public.

Meeting these information needs will require close collaboration between researchers and extension personnel and better communication with local officials themselves. Innovativeness will be called for in structuring and achieving optimal relationships. But, it is clear from Wingspread that separate research and extension efforts will not be enough.

The continued deterioration of rural public infrastructure was another point of concern. Numerous instances were cited of decaying roads, bridges, and other capital facilities. Although they were agreed about the existence of a problem, delegates were less certain about the causes. Some cited the difficulty of obtaining adequate and affordable capital financing as a barrier to meeting community needs. Others cited regulatory problems, particularly with water and sewer systems, where Federal or State requirements forced shifts to costly or inappropriate new technologies. Capital budgeting practices appear spotty and often ineffective, and local officials lack needed information about when improvements or replacements should be undertaken. The absence of comprehensive information at State or national levels inhibits the formation of policies that could address these issues.

The new constraints on public finances prompted participants to rethink local institutional arrangements for service delivery. Major alternatives that may offer cost savings are cooperation with neighboring governments, regionalized service delivery, contracting with public- or private-sector agencies, and turning over service delivery or public facilities to the private sector. Participants questioned whether these arrangements always make the economic sense sometimes claimed for them and wondered where the proper bounds of public responsibility in providing services lie.

Many more questions were raised than could be answered from existing research. Cooperative agreements may generate cost savings, but delegates were uncertain whether they would provide enough incentive for local governments to enter them. Research could usefully clarify the benefit-cost threshold at which agreements will be formed and could explore noneconomic incentives and disincentives, such as political ones, that affect the use of economically desirable service delivery arrangements. Supporters claim many benefits for private service delivery, but whether these outweigh losses in service quality and other costs is an empirical question.

The great variability among rural communities was a recurring and, in many ways, the fundamental theme of the symposium. Despite the overall trend of renewed growth in nonmetropolitan areas, broad statements can be very misleading when applied to individual settings. Many rural communities are in fact not growing. Even where growth has occurred, it is due to a variety of causes, each of which has quite different implications for local service delivery problems. Much has been written about the new population trends, but it awaits analysis of the 1980 Census of Population to learn how the trends are shared among individual communities.

The implications of these differences for rural policy are not well understood. Careful research into the importance of demographic features, as well as geography, governmental form, and public attitudes, could help better inform policy. In the present climate of change in rural areas, special attention is merited concerning the way these changes are likely to affect public finances and community structure.

Participants also agreed on the importance of educating Federal and State policymakers about differences among rural areas and between rural and urban settings. Despite the unique circumstances that define rural communities, participants viewed many rural policies as little more than warmed-over urban solutions that suffer from inappropriateness at best. Rural policies that rest on common national assumptions face the same risk of unintended and damaging effects. The research community can help by clarifying and communicating the important differences.

Attendees agreed that these rural knowledge needs could be better met by developing "ruralists" as counterparts to the "urbanists" who have become so influential in shaping public policies in recent years. At a minimum, delegates felt that increasing the status and visibility of rural studies might help attract and retain the most capable researchers in this field.

Delegates agreed, too, on the value of continuing the kind of discussions among levels of government and with universities that was begun at Wingspread. Followup activities to extend the process are planned. The spirit of cooperation in which delegates came together in Racine symbolizes the newly recognized interdependence among governments and augurs well for the emerging process of communication.

Growth in U.S. Agricultural Capacity and Utilization: We Need to Know More about It

By Clark Edwards*

World population is growing, and it is not certain whether world food supplies will grow in balance with population. Disparate private and public actions in the United States and elsewhere today, in situations seemingly unrelated to the world food situation a decade or two hence, can have major consequences for the well-being of what will soon be 6 billion people living on this planet. Some perceptions of the future reflect an optimistic view of continued food surplus. Others reflect a pessimistic view of Malthusian scarcity. In between are several studies which suggest that longrun prospects for balanced growth of people and food supplies are quite good. However, world balance does not necessarily imply balance by region and commodity. Regional imbalances accelerate world trade. And, longrun world balance does not preclude shortrun instability. Annual fluctuations in supplies and demands can have major impacts on prices, farmers' incomes, and prospects for efficient and equitable adjustments to meet longrun needs.

A broad range of factors affect the longrun prospects for the efficiency and equity with which U.S. agriculture will respond to a steadily rising world population, increasing but fluctuating world food supplies, and increasing levels of world agricultural trade. The equity of the distribution of food and fiber among low-income people both in the United States and in less developed countries is also at issue.

The Economic Research Service (ERS) is expanding its focus on the factors affecting these problems and is reexamining the data base used to describe the food problem and studying the theoretical framework used to explain it. The perspective is on social welfare resulting from adjustments in U.S. agriculture rather than on private profits to those making the adjustments.

The balance of this article explores the scope and complexity of the world food problem from the point of view of the response of U.S. agriculture. In so doing, it indicates why the problem admits of no easy solution. And, it serves as a guide for expanding research on the problem.

The market for U.S. farm products is partly domestic and partly foreign. The foreign component is the net between total foreign demand and foreign supply. Of the three components that describe the size of the U.S. market—domestic demand, foreign demand, and foreign supply—it is foreign supply that is most volatile and least predictable. The size of the market for U.S. farm products is also affected by supplies of food from nonfarm sources, such as the ocean. The longrun problem is usually cast in terms of pressures of world population against food supplies. But, shortrun fluctua tions in the market for U.S. farm products are more a world supply than a world demand phenomenon. U.S. agriculture will likely continue to provide an increasing proportion of the food that enters world trade. The trend and variability of net food demands to the United States need to be viewed by country and by commodity because such imbalances accelerate world trade and contribute to instability, even when the world aggregates are in balance. Domestic and world price, income, and population elasticities of demand need to be reviewed for their implications for price levels, relative prices, commodity mix, and the U.S. balance of payments.

Productivity of U.S. agriculture is high and rising. Productivity is concerned with the quality of food as well as the quantity; quantitative advances are not necessarily accompanied by qualitative progress. Whether productivity continues to rise sufficiently to meet prospective net world food needs will depend on a number of factors. Continued investment in science and research and continued extension of information and assistance are vital to continued growth in U.S. agriculture. Changes in the parity ratio reflect farm and nonfarm economic forces that affect incentives to produce and that influence the level of farm output. The balance sheet of agriculture and the farm income statement depict not only factors which describe the technical production function of U.S. agriculture but also factors which are economic incentives for farmers to produce. Other incentives, such as the quality of life on farms, also affect production. Relative prices of products and inputs affect resource allocation and enterprise combinations. Adjustments to relative price changes affect productivity through increased economic efficiency rather than technical efficiency. Changes in the structure of agriculture—such as size of farm, degree of specialization, and legal form of organization—affect productivity. The trend toward using more and more nonfarm inputs and toward adding more nonfarm value to outputs requires an assessment of changes in agribusiness. An infrastructure not controlled by farmers is important in agricultural productivity. This infrastructure includes the various levels of government and their nonfarm as well as farm programs, the market structure (including cooperative marketing arrangements), schools, experiment stations, extension services, farm organizations, hospitals, and various community facilities. Air pollution—automobile exhaust, for example—affects crops yields and reduces farm output. The infrastructure also includes the general health of the nonfarm economy.

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The availability and utilization of resources are key determinants of farm output. If you want to make U.S. agriculture grow, one way is to provide it with more land, labor, capital, and management. Markets for farm resources have unique features based on characteristics and location of the resource supplies and on the derived demands that reflect imperfect resource substitution in the production process. Some resources are not renewable and change character irreversibly under certain kinds of use. The threat of resource degradation arouses concern for conservation of natural resources and for environmental quality. Some resources used by farmers supersede into what society appears to value as higher uses, while others are moved into agriculture from lower uses. The intensity of land use affects the operation of these markets. Many resources are seldom on the market and are committed to fixed uses by farms, or even by enterprises. Resource fixity affects the responsiveness of agriculture to changing food needs. Rising net worth, increased flows of funds, capital accumulation, and creditworthiness affect farmers' decisions to invest in added resources. The supply response of agriculture is affected by rising capital-to-land ratios, increasing value of human capital, increased use of nonfarm inputs, rising real energy costs, and limits to the availability of natural resources. Past trends have resulted in relatively stable agricultural land requirements, increasing capital requirements, and decreasing labor requirements. Our ability to increase food supplies depends on the extent to which the land, labor, and capital available to agriculture are used to capacity and also on the prospect for change in the trends of availability of resources to farmers. For example, land now in U.S. farms is used far less intensively than it might be, and far more land is suitable as crop and pasture land than is now being used by farmers.

A number of institutions enhance or limit the efficiency and equity associated with U.S. agriculture. Farm product markets are often said to be examples of nearly perfect competition. That may be so, but monopolistic elements are common in the agricultural processing and distribution sector and in many of the input markets. The land market, for example, is treated by location economists as a perfectly discriminating monopoly. Cooperative marketing and vertical integration have modified some farm product and factor markets. Market institutions, including the interference in the markets by governments for purposes of domestic or foreign policy, affect the supply response of U.S. agriculture. The tax structure affects farm income distribution and incentives. Regulations and various legal constraints override free market forces. Legal constraints include legal form of farm organization, ownership of resources, tenancy contracts, private property rights, and access to public lands. Financial institutions, credit availability, and interest rates affect farmers' decisions to invest. Inflation and concomitant changes in institutional arrangements, relative prices, and levels of uncertainty affect farm production incentives. Perceptions of farming as a way of life in a decentralized economy affect the decisions of many families to enter or remain in farming. Institutional arrangements are important in determining the capacity of U.S. agriculture to remain efficient and equitable as it is confronted with increasingly volatile world markets. Fluctuations in final product markets lead to variation in farm prices, carryover stocks, land values, and enterprise combinations. Various institutions need to be in place to protect farmers and to help them absorb fluctuations.

The geographic location of farms relative to resource supplies and product markets affects the supply response of U.S. agriculture. Certain types of farms need to be located on certain types of soil and to have immediate access to extensive supplies of water. The location of farms relative to resource supplies or to product markets affects the type of farming in a region and its profitability. Efficient access to transportation and communication facilities leads to increases in the supply of farm products. Commercial farms have vital economic links to cities though forward (product market) and backward (purchased input market) linkages. The linkages tend to be most effective for farmers located within the matrix of an urban center. Links to the nearby rural economy are strongest through competition for local resources, particularly land and labor. Links to foreign markets are through national institutions associated with imports, exports, and the balance of payments. World geography influences whether or not world balance of aggregate population and food supply is accompanied by regional, inefficient, and inequitable imbalances.

The prospects for growth in the capacity and utilization of U.S. agriculture to meet increasing and fluctuating net world demands for food in coming decades depends on private and public actions taken during the eighties with respect to markets, productivity, resource availability, institutional arrangements, and geographic relationships.

Mexico's Agricultural Dilemma

P. Lamartine Yates. Tucson: University of Arizona Press, 1981, 291 pp., $19.95 (cloth), $8.95 (paper).

Reviewed by D. H. Roberts*

In 1975, as Dr. Yates was writing his extensive two-volume profile of the Mexican agricultural sector, *El Campo Mexicano* (The Mexican Countryside), Mexico exported $1.1 billion of agricultural commodities while importing $911 million of farm products, the most positive agricultural trade balance that the country had enjoyed since anyone had started compiling statistics. By 1980, Mexico's import bill had tripled, but the value of agricultural exports grew only slightly to approximately $1.5 billion. In this 5-year interval, the number of seminars, hearings, and consortiums which attempted to explain why Mexico had suddenly emerged as the United States' second largest customer for agricultural commodities grew in direct proportion to Mexico's import bill. Many studies focused on the implications of this development for U.S. purchases of Mexican oil (the "food for crude" issue); others either noted the impact on migration or damned the transnational corporations. Most studies failed to address the central question, "Why can Mexico no longer produce enough food for her people?"

Yates traces the evolution of Mexico's current agricultural crisis over the past 15 years and, along the way, provides one of the most comprehensive, unbiased analyses in print on either side of the border. Yates' position as an advisor on economic and social matters to both the Government and the National Bank of Mexico over the past 8 years gave him access to data available only in internal documents and out-of-print sources. Professionals charged with analyzing Mexico's agricultural sector who have struggled with conflicting data published by various official sources or who have encountered nonsensical numbers in livestock or land use series will appreciate the author's invaluable guidance in deciphering Mexican data. For this reason alone, Yates' book qualifies as an indispensable reference. But, *Mexico's Agricultural Dilemma* is more. Yates examines agricultural prices, credit expansion, extension services and land tenure—among several other topics—with policy reorientation in mind. He asks what sort of agriculture will be appropriate for Mexico when there are nearly 100 million Mexicans, all more prosperous and demanding than the 68 million of 1980, and he proceeds to suggest measures that will be needed to satisfy the social and economic aspirations of Mexican society during the eighties and beyond.

The book's thoroughness, a strength from the viewpoint of academic scholarship, is a weakness as regards readability. Yates writes in a simple, declarative style, but only devotees of the study of Mexican agriculture will find the author's detailed comparisons of data sources and explanations of derived data interesting. For those students of the economic development of Latin America or of the energy-rich nations, a reading of the first and last chapters would probably suffice. Indeed, Yates does not pretend to have written this book as a guide or text with implications for all, emphasizing as he has Mexico's agricultural idiosyncrasies.

Yates begins with Mexico's "golden years" during which its agricultural sector by any standards was a success. Annual production from 1940 to 1965 rose at the astonishing rate of 5.7 percent, far faster than in any other Latin American country. During this period employment increased, incomes rose, and the nation began to march the first few miles along the road toward generalized human welfare. As Yates points out, Mexico was one of the few developing countries in which the agricultural sector was sufficiently virile and dynamic to underpin advances in the social and economic well-being of the population as a whole. Beginning in 1965, a number of physical, technical, social, and economic factors began to converge that slowed growth in the sector "from a glorious gallop into a temperate trot." The single greatest brake on growth in Mexico's agricultural economy was the slowdown in the expansion of harvested area, the result of the growing costs of bringing increasingly marginal land into production.

At the same time that growth in the production of farm commodities began to slow, demand for these products started to accelerate, stimulated at first by a population of 45 million growing by more than 3 percent a year and later by a society made more prosperous by its oil reserves. Thus, by the end of the seventies, the country had drifted into the position of becoming an importer of basic foodstuffs. It had long been assumed that Mexico had sufficient resources to feed itself, while contributing substantial amounts of exports for its import-substitution development plan. Mexican policymakers also believed that technical progress would assure a continuing growth of output and of farmers' incomes. The discovery that all these factors were no longer inevitable provoked a rather violent reaction in public opinion—and a frantic search for remedies. By the nature of the political process, most of these remedies, such as price-support increases and credit expansion, were short-term. But agriculture is inherently an activity in which situations change slowly and investments take years to achieve, as Mexican policymakers discovered during the late seventies. Hoping to counteract 15 years of benign neglect of the agricultural sector, the Government in March 1980 announced a comprehensive

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food and fiber plan, the Sistema Alimentario Mexicano (SAM) to achieve self-sufficiency in basic food and feed products by 1985.

Yates next turns to the future and assesses demand prospects under two scenarios—high and low alternatives. The results of his analysis present a formidable challenge for Mexican producers. The low alternative yields an annual increase in total consumption of 4.2 percent, whereas total consumption would grow by 4.9 percent annually under the high alternative. Yates examines the implications of his demand projections and finds that, even allowing for an optimistically estimated rise in per-acre yields, Mexico would have to add something between 14 and 20 million additional acres of arable land to the present land base level within the next decade if domestic production is to maintain its share of total consumption.

The bulk of the book surveys the availability of resources—physical, technical, economic, and social—for increased agricultural production and assesses the contribution these resources could make toward this goal. Yates finds that Mexico's land tenure system is the severest constraint to production gains. The agrarian reform code has not been substantially revised in over 70 years, which has immobilized the farm population. For example, producers are limited to 200 hectares of rainfed land or to 100 hectares of irrigated land and, until 1981, were not permitted to operate a mixed enterprise (crops and livestock). Contradictory addendums have also been tacked onto the initial code over the years, leading to widespread abuse of laws by farmers and arbitrary enforcement by officials. One section of the code limits ranches to 800 hectares whereas another permits a rancher to possess the amount of grassland necessary to maintain 500 head of livestock, which would amount to 25,000 hectares in some areas.

To exacerbate the present tensions in the countryside, populist politicians propagate the myth that if the State would but divest the remaining large landowners of their holdings, there would be plenty of productive land for the remaining 4 million landless petitioners. The result of current land tenure laws and enforcement of these laws has been uncertain farmers who are unwilling to make investments in their operations for fear of having their land capriciously expropriated later.

Yates proposes an ingenious scheme of phasing out the most anachronistic and ambiguous aspects of the land tenure system while retaining the characteristics that are clearly at the core of the Mexican populace's conception of proprietorship. Above all, Yates' proposals would add flexibility and adaptability to a system which is breaking down under the weight of its own restrictions.

Yates concludes that Mexico cannot hope to achieve self-sufficiency in basic food and feed grains, and so he tailors his recommendations for land tenure reform, price policy, credit, and extension and research to stimulate production of a wide variety of commodities and livestock. This solution, of course, opposes the prevailing policy direction of the Mexican Government, and many Mexican experts with different political perspectives would no doubt challenge Yates' conclusions. As the author recognizes, many of his proscriptions would be extremely difficult to implement, but he warns policymakers against relying on Mexico's oil export revenues to buy a solution to Mexico's growing reliance on food imports. He points out that Mexico, unlike all other major third-world oil exporters (except Indonesia) is a country with a large population. For Mexico to attain the same export value per capita as Venezuela, for example, Petroleos Mexicanos (PEMEX) would have to export 9.3 million barrels of oil a day compared with the 1.2 million it exported in 1980.

Despite any reservation that readers may have concerning the author's policy recommendations, they should recognize what a contribution to the field *Mexico's Agricultural Dilemma* represents. Yates has done a remarkable job of sifting data and evaluating Mexico's demand and supply balances for the eighties in the most comprehensive treatment of Mexico's agricultural sector available in English.

Modeling and Measuring Natural Resource Substitution

Ernest R. Berndt and Barry C. Field, eds. Cambridge, Mass.: MIT Press, 1981, 314 pp., $35.00.

Reviewed by Michael LeBlanc and Thomas Lutton*

The title of this book suggests that its focus is on natural resources; however, the actual content is broader. Because the authors examine resource substitution simply as another input in production, the modeling approaches they discuss can be applied to many problems of input use. The book can best be categorized as econometric applications of duality theory to input substitution and technological change.

Except for the introduction, the individual chapters are revisions of papers presented in December 1979 at a conference funded by the National Science Foundation. They are grouped by three major topics: (1) empirical results of resource substitution and resource-saving technologies, (2) problems arising from recent research, and (3) dynamic models.

The introduction provides a useful chronological survey of empirical applications of duality theory. It reviews Nerlove's (*5*)[1] estimation of electricity-generating technology, McFadden's (*4*) and Diewert's (*2*) work on flexible functional forms, and Christensen, Jorgenson, and Lau's (*1*) analysis using transcendental logarithmic functions. The introduction indicates that in 1961 Heady and Dillon (*3*) had examined a second-degree polynomial logarithmic function (later known as the translog function) and had provided least-squares regression estimates of a square root transformation, which is a special case of the generalized linear production function introduced by Diewert.

The introduction sets the conceptual tone for the book. That is, scarcity of natural resources increases prices, and it causes substitution of inputs in production, technological change, higher output prices, and reduced consumption of resource-intensive goods. If substitution possibilities are limited and technological change is slow, then economic pressures from resource scarcity are likely to be significant.

The first two sections concentrate on using dual cost functions to derive factor demand relationships conducive to econometric estimation. These sections provide a valuable survey of systems estimation techniques that use flexible functional forms. The systems approach highlights the interrelatedness of all inputs in production.

Each article includes an empirical application. Industries are classified by the type of factor substitution and technological change (Jorgenson-Fraumeni and Moroney-Trapani) and are examined for endogenous factor prices (Anderson). Single-period market equilibrium is assumed in each case. The distinctions between long- and shortrun effects, based on whether the data are cross-sectional or time series, are discussed.

By focusing on econometric applications, the book neglects the potential contribution of mathematical programming to analyzing input substitution. Programming models allow researchers to analyze the effects of input price changes on factor substitution and technological change in a deterministic framework. The Kopp-Smith paper blends an econometric approach with pseudo-data generated by a programming model.

All the analyses, except for Kopp-Smith's, use aggregate data. They contain virtually no discussion of firm-level modeling. Industry- and sector-level models are specified and estimated with little theoretical justification. This limitation detracts from the quality of the conceptual models. Furthermore, the applications rely extensively on the translogarithmic function. The translog is only one example of many flexible forms that one can use to model input demand.

The third and last section of the book, dynamic models, is the most interesting. Berndt, Morrison, and Watkins present an excellent survey of dynamic models. The assumption of single-period market equilibrium is relaxed and input disequilibrium models are presented. The first generation of models assumes that firms are unable to adjust factor demands instantaneously to longrun equilibrium levels. This generation of models is represented either by generalizing a partial adjustment process to an input demand system or by utilizing a restricted cost function where one input, typically capital, is assumed to be quasi-fixed. Brown and Christensen apply a restricted, variable cost function to analyze U.S. agricultural production.

The second-generation dynamic models are an important addition to the theory and methodology of analyzing input use. These models are based explicitly on dynamic economic optimization that incorporates adjustment costs for quasi-fixed factors. Unlike first-generation models, speeds of adjustment of quasi-fixed factors to longrun equilibrium levels are endogenous and may vary through time. Shortrun demand equations depend on input prices, output, and stocks of the quasi-fixed inputs. The dynamic adjustment path to longrun equilibrium is based on economic optimiza-

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[1] Italicized numbers in parentheses refer to items in the References at the end of this review.

tion at each point in time. Denny, Fuss, and Waverman provide an example of a second-generation dynamic model.

In the past decade, there has been a dearth of stochastic input demand studies in agricultural economics. Spinks and Dahl (*6*), in an extensive bibliography of economic input studies, reveal that the literature contains few input demand analyses using econometrics. The lack of attention to this type of analysis can be attributed to the difficulties of formulating an agricultural input demand system which is conducive to econometric estimation and to the lack of input quantity data. Yet, the effects of input prices, such as capital, energy, land, and water, are crucial to agricultural production and food supply. Agricultural policy analysis is difficult without an understanding of the potential affects of input price increases on production costs, output, and input use. The dynamic approaches discussed at the end of this book provide a valuable conceptual framework from which to address this problem. The agricultural production process is itself stochastic; expected and actual output may differ substantially, depending on the effects of weather. The assumptions used to model the manufacturing sector may be inappropriate for agriculture. The dynamic disequilibrium framework offers an interesting alternative to conventional agricultural models.

The book is an ambitious undertaking. Although it has inadequacies, it clearly indicates the interrelatedness of input use, capital formation, productivity, and prices. It provides a broad view of econometric approaches from which researchers can analyze the derived demand for inputs. It is an excellent state-of-the-art survey of modeling resource demand.

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Different measures of rate of sales, such as pounds per 100 customers, pounds per store, and dollars worth of apples sold per $100 of sales of all commodities, involve different concepts. There are conceptual differences that are more than just a question of whether distance, for example, should be measured in terms of inches or centimeters. Thus, the criteria for choosing a measure of rate of sales should include the utility of the different measures assuming no sampling error as well as sampling variability and biases.

Earl E. Houseman
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Environmental Regulation and the U.S. Economy

H. Peskin, P. Portney, and A. Kneese, eds. Washington, D.C.: Resources for the Future, 1981, 163 pp., $15.00 (cloth), $5.95 (paper).

Reviewed by Stan Daberkow*

Regulation continues to hold the interest of producers, consumers, the Congress, the current administration, and, of course, economists. The thrust of this attention has been changing, however. We are no longer in an era of regulatory expansionism, and, in fact, some suggest that contraction either has begun or should begin. This book presents a compilation of articles that spotlight the state-of-the-art of environmental regulation policy and analysis. Although the book concentrates on the relationships between environmental regulation and the aggregate U.S. economy, agricultural economists may find the political analyses, methodological techniques, and policy design discussions stimulating.

Bosworth begins by discussing the past and present political economy of environmental regulation. During the sixties and early seventies, economic growth was taken for granted. Public policy focused on inflation, unemployment, and the distribution of income and on the protection of workers, consumers, and the environment from the externalities of an industrial society. Public policy is now focused on productivity and growth. Regulation becomes an issue because regulation implies increasing costs of production and additional competition for scarce resources. If high unemployment and foregone production are incurred to abate inflation, Government regulations which have the effect of price increases will not be tolerated. Bosworth also discusses the relationship between real income and productivity. He suggests that proposed and current environmental regulations will garner little support because individuals perceive them as reducing real income. This situation is even true if benefits of regulation exceed costs because the unquantifiable beneficial effects may be less obvious than price or output effects.

Portney discusses: (1) the expenditures by consumers, industry, and Government to meet environmental regulations designed to correct market failure arising from externalities or imperfect knowledge and (2) the methods used by economic modelers. He states various caveats on the use of econometric models due to inherent limitations of mathematical systems and the use of flawed data. He compares environmental expenditure sources (for example, Bureau of Economic Analysis, Council of Environmental Quality, Environmental Protection Agency, McGraw-Hill, and U.S. Census) with respect to data collection and analysis. Environmental regulation modeling efforts typically consist of at least two simulations—one with spending and other changes induced by regulation and one without the spending. The difference reflects the effect of regulation. Although Portney recognizes these models have weaknesses (for example, inability to adequately incorporate the benefits of regulation such as reduced risk of illness or death, reduced medical costs, reduced cleaning costs, and increased agricultural yields), he defends the use of large macromodels because of their comprehensiveness (that is, trade, unemployment, inflation, investment, price, and output effects) and their capacity to make predictions which are integrated and simultaneously determined.

Haveman and Christiansen discuss U.S. productivity growth as influenced by environmental regulation. Their discussion is threefold: (1) concepts, measurement, and status of U.S. productivity; (2) factors affecting productivity measures; and (3) the part that environmental regulation plays in productivity growth. The first part of their article concerning concepts and measurement is weak and does not properly set the stage for what follows. The changing composition of U.S. output (that is, agricultural goods to industrial goods and manufactured goods to a service economy), declining research and development as a percentage of gross national product, the dramatic increase in the proportion of unskilled women and teenagers in the labor force, declining capital/labor ratios, and rapid and large increases in energy prices are factors in addition to regulation which influence productivity. The authors produce hypotheses and review studies which attempt to quantify the impact of regulatory activity on productivity. They conclude that regulation causes measured inputs to increase whereas measured outputs change very little; hence, economic welfare may be increasing while input/output ratios increase.

Peskin elaborates on the Haveman-Christiansen hypothesis by investigating the extent to which changes in the quality of the environment resulting from regulation are captured in the national accounts. He suggests modifications in the current national accounts so they can more closely reflect the changing quality of the environment.

Harrington and Krupnick present an extensive historical perspective on pollution policy that includes the major 1977 changes in regulations. Recent procedural changes, such as marketable pollution permits, effluent charges, and other economic incentive devices, are contrasted with technology- or engineering-based standards. As current industrial air- and water-pollution policies come under attack for imposing excessive costs and retarding innovation and investment, these alternatives will gain greater acceptance.

*The reviewer is an economist with the Economic Development Division, ERS.

Ridker and Watson examine the longrun effects of environmental regulation on the U.S. economy. Using dynamic input/output techniques and assumed levels of economic growth, population growth, and technological change, the authors make regional forecasts to the year 2025. Agricultural economists interested in nonpoint sediment and pesticide runoff from agricultural production will find both issues treated explicitly in the model. The authors conclude that "substantial control of the common mass pollutants can be achieved without undue interference with the national economy" (p. 150). This is the least documented article in the book, and, partly because of the nature and size of the research project, the reader must obtain the cited literature to determine the assumptions used.

The book's material is germane for agricultural economists interested in the environment and natural resources. Casual observers of resource policies will find the book readable because the authors keep the technical aspects of modeling to a minimum and emphasize policy and data. The book's major fault is its somewhat disjointed nature resulting from the variety of topics. One gets the impression that the book was quickly cast in an effort to report environmental policy and economic research activity at their zenith. Despite this shortcoming, it is a good reference for pollution policy, data sources, mensuration issues, and environmental modeling.

In Earlier Issues

With expanding use of electricity, improved roads and mechanical power, and further consolidation of institutions in the trading centers, less differential between farm and city dwellers is indicated. Government will continue to have a large role in protecting farmers from natural disasters and economic crises. Farm depressions have been forerunners of general depressions, and these are no longer viewed as acts of God, but as man-made; as such they are subject to human control. There is scarcely a farmer in the United States at mid-century who is not familiar with the appearance of a Federal Government check; in 1930 there was scarcely one who was. Migrants and other farm laborers and many small operators have received relatively little if any benefits from recent ameliorative agricultural programs. Legislation has favored the "haves" and left the "have-nots" little better off than they were before.

Lowry Nelson
As paraphrased by Arthur F. Raper
Vol. 7, No. 2, April 1955, p. 56

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Articles: Van Duyne, "Food Prices, Expectations, and Inflation"; Jesse, Johnson, Marion, and Manchester, "Section 2 of the Capper-Volstead Act"; Mines and de Janvry, "Mexican-U.S. Migration"; Park and Shabman, "Nonpoint Pollution Control Constraints"; Conrad, "Managing a Multiple Cohort Fishery"; Blomo, Nichols, Griffin, and Grant, "Modeling the Gulf of Mexico Shrimp Fishery"; Tsoa, Shrank, and Roy, "U.S. Groundfish Demand"; Ray, "Translog Cost Analysis of U.S. Agriculture"; Sumner, "Farmers' Off-Farm Labor Supply"; Lopez "Energy Prices in a Small Open Economy"; Ahsan, Ali, and Kurian,"Agricultural Insurance Theory"; Dixon and Martin, "Forecasting Pork Production with Random Coefficients"; Tyrrell and Mount, "A Non-Linear Expenditure System." Notes: Griffin and Bromley, "Runoff as a Nonpoint Externality"; Wohlgenant and Hahn, "Dynamic Monthly Demand for Meat"; Chavas and Johnson, "Supply Dynamics for Broilers and Turkeys." Plus more Notes and Book Reviews.

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